After Irene: Adaptation, Policy, and Management

Middlebury College

Environmental Studies Senior Seminar

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Table of Contents

1. Introduction

On August 28, 2011, Tropical Storm Irene hit Vermont. Four to eight inches of rain rapidly fell throughout the night with the greatest precipitation in towns on the eastern side of the Green Mountains. Rivers like the Mad, only a small creek the day before with a flow of 100 cubic feet per second, jumped its banks and surged to a flood level of 23,000 cubic feet per second, or twice the flow of the Colorado River through the Grand Canyon. The massive and widespread destruction brought by these record floodwaters along Vermont's creeks and valley bottoms was only comparable to the Great Flood of 1927. More than 500 miles of road and 200 bridges were wiped out, a dozen communities were entirely isolated and over 1,600 homes were damaged and 700 completely destroyed. At great price, Irene exposed Vermont's vulnerability to disasters of this nature.

The emergency response in the aftermath of Irene, however, was an incredible testament to the strength of Vermont's communities and to the ability for this state to turn devastation into restoration; vulnerability into resilience. As the state enters an increasingly uncertain future in the context of already-induced global warming, it will be these qualities that guarantee a future of transformation; of rethinking our relationship to rivers, and to each other.

Flooding is already the most frequent, damaging, and costly natural hazard experienced in Vermont. Climate change models, however, show that this hazard will increase in frequency, as Vermont becomes a wetter state. It was previously thought that a storm the size of Irene was the hundred-year storm. This does not mean that a storm of this size will come every 100 years, but means that each year there is a 1% chance of a storm of this scale. Recent studies have found that this probability is more realistically 33% to 5% when climate change is considered. Irene could be the new three to twenty-year storm.

The following report presents the methodologies and findings of the Middlebury College Environmental Studies Senior Seminar in the Spring of 2012, entitled "After Irene: Adaptation, Policy and Management." The report will open with an exploration of historic river management practices and their compatibility (or incompatibility) with a rapidly warming world. A cost-benefit analysis was applied to Liberty Hill Farm in Rochester Vermont as a framework to assess the long-term, repeated costs of river modifications and to estimate the costs of different management options. A repeat damage assessment of transportation networks in Rochester,

Hancock and Plymouth follows, in order to explore ideal policy measures for areas increasingly vulnerable to flood damage. The assessment has been nested in current and future climate projections for the state, as well as funding availability (from both the state and federal government).

Using the technical assessments and recommendations of this report's opening chapters as a launching point, the third chapter will explore the sociological and psychological implications of Tropical Storm Irene. After conducting a literature review of psychological and sociological research on the behavior and motivations of floodplain residents, a survey was designed and disseminated to residents in Hancock, Rochester and Plymouth. A summary of findings regarding the salience of climate change among floodplain residents, their likelihood of relocating and perceptions of interactions with government officials has been included. To conclude, this report will propose policy recommendations regarding the adaptation of housing and transportation infrastructure, drawing on the wealth of knowledge at the state and federal level.

Ultimately, this work stems from the belief that despite Vermont's obvious leadership on questions of climate change mitigation, adaptation will be necessary in the context of already induced warming. Vermont also needs to understand risk as a largely human creation—as something that can be either exacerbated or diminished through public policy, community planning, and individual action. We hope that this work will prove useful to communities, policy makers and individuals across the state as they attempt to transform our state after Irene.

2. Documenting Historical Channel Migration of Two Vermont Rivers

Zach Doleac, Wyatt Komarin, Mark Little, Jen Liu, Leah Nagel, Devin Perkins

I. Project Background

A. Vermont Before and After Irene

On August 28, 2011, Tropical Storm Irene picked up water vapor from the Atlantic Ocean, created multiple thunderstorms and resulted in heavy rains and high winds in the Northeastern United States, specifically in Vermont. The storm dumped 8.5 inches of rain in Rochester and 7 inches in Plymouth (NOAA 2011), causing massive flooding throughout the state that destroyed homes, washed out roads and left a dozen towns completely isolated. The destruction that Irene left in its wake has served as a wake-up call for many by highlighting the vulnerability of much of Vermont's infrastructure to flooding and other natural hazards. Much of this vulnerability comes from the fact that many roads, houses and agricultural lands are located next to rivers, in floodplains and near the confluence of steep mountain streams and valley floors. In many cases, that vulnerability is exacerbated by attempts to protect upstream infrastructure located near sensitive river channels. These upstream modifications to the river channel are designed to keep the river in a human-designated area**.**

B. Geomorphic Impacts of Historical Management

Traditionally, river management practices have focused on keeping rivers in their historical (often human-altered) locations and preventing potential erosion or floodplain access (Kline 2010). Any changes in river behavior or position from these locations were treated as inherently negative, and as a result consideration of science-based and river-minded management was impossible and containment practices such as dredging and bank armoring were encouraged. These practices, however, can have unintended consequences.

Throughout Vermont's history, river management has been a constant, ongoing process. Rivers were moved around to power mills and make way for farmlands, dredged after floods choked channels with sediment and armored to prevent erosion damage to property and infrastructure. However, in recent decades the science of stream geomorphology, or the study of

the natural tendencies of rivers, has shed light on the unintended consequences of these practices through a greater understanding of river dynamics.

Stream channels—their width and depth, meander pattern, and slope—reflect an array of variables including water flow, the transfer of sediment and debris, and the valley type within which the stream is located (River Management Program 2004). If conditions are stable for a long time, a river that is just wide, deep, and long enough to transport the water and gravel produced in its watershed will remain stable, with minimal erosion and movement even in flood events. However, changes in conditions within the watershed that alter inputs (e.g. deforestation leading to increased erosion) or the shape of the river channel (e.g. straightening or dredging), will cause the river to adjust until it reaches a new stable state resulting in increased erosion and changes in depositional patterns and stream course (Figure 1a) (River Management Program 2004). Because these adjustments often conflict with human infrastructure, the adjustment process (e.g. bank erosion) is often arrested and can exacerbate the initial problem (e.g. an incised channel) and create a constant cycle of alteration where the river is never able to reach a new stable state (Figure 1b).

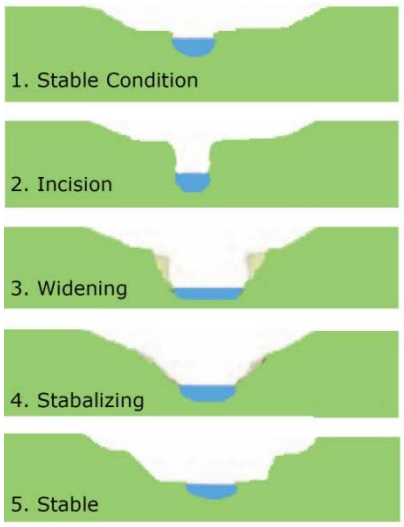


Figure 1a. The adjustments that occur post-streambed incision in an unmanaged stream as it attempts to re-attain a stable state. Incision results in lateral erosion and eventual bank failure, followed by stabilization.

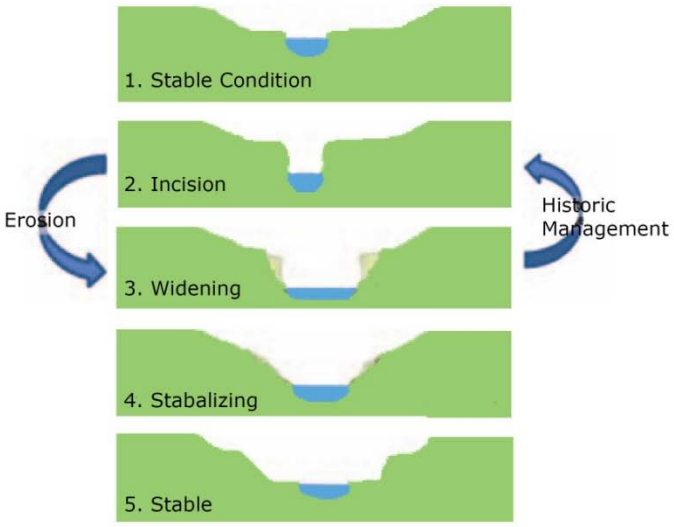


Figure 1b. As management practices are installed to prevent bank failure, lateral erosion is prevented and only the streambed is vulnerable to erosion, further incising the channel and continuing the cycle.

Source: image adapted from http://www.fairfaxcounty.gov/nvswcd/newsletter/enjoyrestorestreams.htm

The alterations mentioned above all have impacts on stream dynamics through changes to different aspects of the river corridor (Appendix A). Straightening a river corridor to make room for farms and roads can have several unintended consequences. Straightening leads to an increase in the slope of the stream by shortening the length of the stream over a given elevation gradient. This leads to an increase in flow velocity and therefore channel erosion (EPA 2005). Another side effect of this increased velocity and erosion is increased downstream sedimentation, as the faster-moving water erodes more and is less able to deposit sediment (Brooker 1985). This condition is exacerbated by the absence of meander bends, which decrease the velocity of the water and also increase the ability of a stream to absorb flood damage (EPA 2005).

A second management practice that often goes hand in hand with straightening is dredging. Dredging to remove sediment, whether for gravel extraction or to protect land use investments, alters the dimensions and streambed composition of the river and increases the amount of additional sediment that the river is capable of transporting, often resulting in a net loss of soil and nutrients from a watershed (Kondolf 1997, Kline and Cahoon 2010). Where dredging prevents floodplain access and therefore increases the flow of water within the channel, it increases the stream's power and therefore its capacity to transport materials—or in other words, the stream's capacity to erode its channel (River Management Program 2004). By altering streambed composition and fundamentally changing the geomorphology of the stream, dredging can also have significant detrimental impacts on water quality and on aquatic communities, through increased sedimentation, the degradation of spawning habitat for economically important fish, species and changing food availability for stream macro-invertebrates (Kondolf 1997, Brown et al. 1998, Kline 2011).

Further, these impacts are not simply limited to the particular location of human alteration; dredging can result in bed degradation upstream as the river adjusts its slope and increased sedimentation downstream resulting from the increased erosion mentioned above. According to stream geomorphic assessments (Appendix A) carried out throughout the state, nearly three quarters of Vermont streams are incised to the point where the stream can no longer reach its natural floodplain, triggering the impacts listed above and additionally preventing important ecosystem services including flood mitigation and nutrient uptake (Kline and Cahoon 2010).

The increased channel erosion that stems from this increase in stream velocity is especially problematic in more developed areas, where infrastructure encroaches on the channel and is therefore built on land that is particularly vulnerable to erosion. As a result, erosion prevention is required to protect this property, usually in the form of bank armoring. In Vermont, the most common type of bank armoring in use is rip-rap, or any graded stone or crushed rock used to stabilize streambanks. Rip-rap impacts can vary depending on the shape and landscape context of the armoring. Rip-rap armoring prevents lateral streambank erosion, but often exacerbates the erosion of the streambed (Fischenich 2003). Together with dredging, bank armoring is used to keep rivers in their existing channels and prevent them from flooding or eroding encroaching structures.

This flood prevention aspect is crucial to understanding the impacts of human management on river systems. All of the management practices discussed above can be used to prevent a stream from accessing its floodplain, and are often quite effective—at that particular location. Floodplains are extremely important for both geomorphic and ecological processes. They are very effective in mitigating downstream damage: floodplains allow a river to expend some of its energy and can provide floodwater storage, both of which reduce flood force and velocity downstream and decrease flood damage. They also provide a variety of other services ranging from water filtration to preservation of wildlife habitat to aesthetic and cultural opportunities (Assembly 2004). From a geomorphic perspective, however, the most important floodplain services are the flood force and velocity benefits mentioned above and the opportunity they provide for the river to discharge some of its sediment load. In spite of all of these benefits, floodplains are often managed to prevent flooding—because when it is farmland or houses in the floodplain, all of that sediment deposited in your field or backyard makes these benefits seem trivial. As a result, the majority of Vermont streams have very little contact with floodplains along their course; of the 1,371 miles of stream that have been measured under stream geomorphic assessments, 73.7% have lost the ability to access their floodplains (VRMP 2009 APUD, Kline and Cahoon 2010) and nutrient loading in final depositional locations such as Lake Champlain has become a significant problem in the state (Kline 2010).

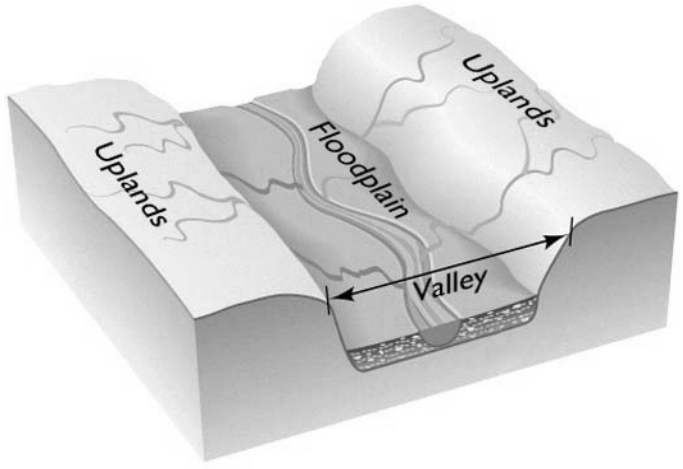


Figure 2. A schematic of a Vermont valley, with upland streams feeding into larger streams on the valley floor. Note the meander bends in the river and the extent of the floodplain. Source: legacy.belmont.sd62.bc.ca.

So far, this discussion of stream geomorphology has focused on management practices and their impacts on managed streams—specifically those streams that tend to come into conflict with human infrastructure because they are located in valleys level and large enough to be ideal for construction and farmland (Figure 2). However, there is an entire category of streams that, while largely unmanaged, has a significant impact on human infrastructure during flood events. These streams are located in steep, narrow valleys carved into bedrock and glacial deposits of gravel and clay; while they are generally small streams with low flows, during flood events they can turn into raging torrents capable of transporting large boulders. These streams are very important in considering flood risk in Vermont, as over two-thirds of the state's 23,000 miles of stream fall into this category (Kline and Cahoon 2010). Due to their steepness and the nature of their corridors, these streams are typically transport reaches (Appendix A) particularly during flood events when the increased water volume and velocity of the stream enable them to transport high volumes of large-grained sediment. These sediments are transported until the water velocity decreases enough to allow sediments to settle out, usually when the river approaches the flatter valley floor. This area of high sediment deposition is known as an alluvial fan (Figure 3). During flood events, so much sediment is deposited in these fans that the existing stream channel is choked with sediment and the stream is forced to take an entirely different path through a process known as avulsion (Appendix A).

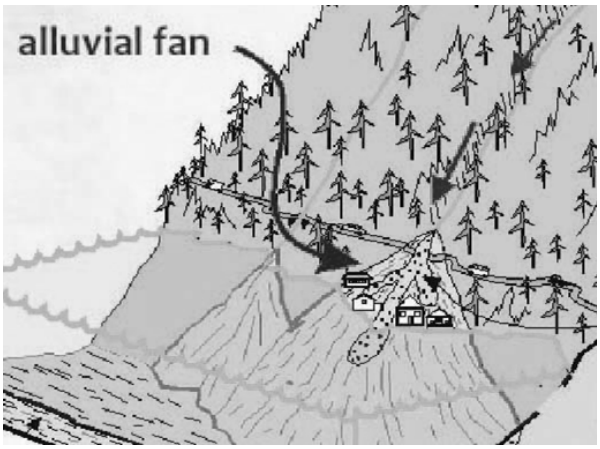


Figure 3. An alluvial fan (Appendix A) at the base of a mountain stream. This figure emphasizes both the restricted nature of the upper reach and the various historical channels within the fan, as well as the potential for development on the fan itself. Image adapted from http://www.nrcan.gc.ca/earth-sciences/products-services/mapping-product/geoscape/vancouver/6361.

When and where channels will become choked and where the water will go next is entirely unpredictable, so for management purposes it is safe to say that all development located on these alluvial fans faces a high probability for flood damage.

C. Vermont River Management Program

In recent years, the Vermont Department of Environmental Conservation (DEC) has begun to reevaluate these historical practices and their focus on how to contain or manage stream flow. After the flooding throughout much of the state in 1998, the Vermont River Management Program (RMP) was created with the central management goal of applying the principles of fluvial geomorphology to improve stream stability and function (River Management Program 2001). In working towards this goal, human-related development must both withstand running water and preserve the current sediment regime to avoid further disrupting the stabilization process (River Management Program 2004). The program is almost entirely incentive-based, with the only regulations on altering stream dynamics in the form of town-by-town zoning regulations and state river alteration permits for any projects involving significant alterations of the stream channel.

Aside from regulating (or encouraging regulation) of stream channel alterations and new developments in vulnerable areas, the RMP is actively working to minimize human-river conflicts by arguing that new development in vulnerable areas should be restricted and by restoring rivers to a more natural state where possible. The program addresses the first goal by

working with state and local officials to revise zoning codes to restrict development within flood-prone areas and move beyond traditional static buffers (Kline and Cahoon 2010). In working towards the second goal, the RMP works to restore natural river function such as meandering and floodplain access to decrease downstream erosion and flood hazards and to restore some of the historic functionality of these reaches. In order to determine the ideal location for this restoration, the program conducts stream geomorphic assessments (SGAs) to evaluate the physical processes and features of Vermont rivers, how humans have impacted these process over time, and the vulnerability of different sections to changes in shape or water flow. For specific locations, these assessments evaluate if a stream is undergoing any adjustment processes at that location, as well as the sensitivity (Appendix A) of the stream (Department of Environmental Conservation 2001). Using the information collected through these SGAs, the RMP must make decisions that shape land use and the design of future development and infrastructure (River Management Program 2004).

When making large-scale management decisions, the RMP implements a basin plan that involves prioritizing reaches for conservation. The most critical reaches are those that are minimally disturbed and those strategic sites that are highly sensitive and have the potential to cause significant upstream and downstream changes (VT DEC 2001). One tool that addresses these conservation goals are stream alteration permits (SAP). Even more substantial, however, are efforts to limit and potentially remove human impacts from especially vulnerable stretches to allow for restoration of natural stream function and the benefits associated with that function. The primary mechanism through which the RMP approaches this goal is through placing that land into a river corridor easement or buying out the landowner entirely.

As emphasized above, much of the land that could potentially be utilized for these purposes tends to be developed or under cultivation. These reaches are conserved through river corridor conservation easements where possible, where the landowner sells the rights to develop their land or put it into production. These easements serve the dual purpose of mitigating flood damage downstream and saving landowners the long-term costs of constantly fighting the river using traditional management practices; however, there are costs associated with these easements that can be problematic for landowners in the long run.

It is important to note that not all repeatedly damaged areas should be placed into easements; as the DEC emphasizes in its Guide to River Corridor Easements, even when

considering the above factors, “traditional management practices” are still appropriate in some cases. This is especially important in light of the fact that much of the land that is most at risk for flooding and/or erosion is under cultivation, putting a disproportionate burden on farmers and the rural community (a situation that is exacerbated by upstream modifications, which are often most extensive in more densely settled areas, as well as the fact that the best agricultural soils tend to be in floodplains). River corridor easements, where appropriate, can be powerful alternatives to traditional management practices; however, they are often a very tough sell in a place where property ownership is so deeply embedded in the culture of the region.

D. Post Irene Management

Much of the work that the RMP has done in the wake of Tropical Storm Irene has been to try to steer the rebuilding process in a sustainable direction by balancing the goal of achieving river stability (based on geomorphic and ecologically sound practices) with societal needs and economic realities. In the wake of Irene, residents were keenly aware of the devastation that flooding can cause, and in many cases were willing to place their land in corridor easements or apply for a complete buyout that they might not have considered at all under other circumstances. In these cases areas identified as conservation priorities by the stream geomorphic assessments were targeted. For example, flood-prone reaches in the valley that could be completely or partially restored as a floodplain were considered priorities for easements or other alternative management strategies, while developments at the base of an alluvial fan that were severely damaged during the flooding were targeted for buyouts (Todd Menees, personal communication).

In documenting the historical costs and ramifications of repeated river corridor modifications and providing a cost-benefit framework for weighing different management decisions, our group hopes to raise awareness among both policymakers and residents about the goals and current work of the Vermont Rivers Program, and to allow them to better assess the long-term costs of river modification and therefore make more informed decisions that balance the needs of our rivers and the health of the individuals and communities that live along them.

II. Project Brief

Goals:

1. Document historic channel migration
2. Document historic management of river corridor
3. Conduct a cost analysis of different management practices that have been implemented and compare costs of different management options with costs of repeat damage

Partners:

- Ethan Swift – Watershed Coordinator, Vermont DEC
- Kristen Underwood – South Mountain Research and Consulting
- Gretchen Alexander – River Scientist, Vermont DEC
- Bob and Beth Kennett – Liberty Hill Farm, Rochester
- James Leno – Road Foreman, Hancock
- Larry Lynd – Road Foreman, Plymouth
- David Mears – Commissioner, Vermont DEC
- Todd Menees – River Management Engineer, Vermont DEC
- Sue Minter – Deputy Secretary, Agency of Transportation, Irene Recovery Officer
- Mary Russ – Executive Director, White River Water Partnership
- Ned Swanberg – Flood Hazard Mapping Coordinator, Waterbury DEC

Geographic focus:

- Rochester, VT
- Plymouth, VT

III. Methods

A. Town Selection Process

The towns of Rochester and Plymouth and their respective watersheds (Figure 4) were chosen in conjunction with other class members after input from our community partners about the needs of the towns and the extent and type of their damage, as well as through firsthand observation of flood damage. Both towns suffered significant damage following Tropical Storm Irene, as well as from previous flooding events. For Plymouth, significant flood events include the years 1927, 1936, 1973, 1976, and 2011; while for Rochester 1927, 1938, 1973, 1998, and 2008 were especially significant. In all cases, the structural damage that occurred was compounded by the geographic isolation of the towns. Both towns are very small with limited operating budgets, and therefore do not have the resources to conduct the type of historical and cost-based analyses of river management our group was charged with completing. Another

important factor in our decision was the presence of substantial evidence of historic river channel modification including straightening, bank armoring, dredging, and loss of floodplain access along almost the entire extent of the rivers within the town boundaries. Finally, we found significant community interest in our project.

Plymouth

Plymouth is located primarily in a narrow mountain valley, and as a result much of the damage sustained was not due to inundation flooding but rather due to flash floods from tributaries to the Black River coming down the mountain. Existing infrastructure at the base of these tributaries, such as bridges, houses, and roads that are built on the alluvial fans of these tributaries proved particularly vulnerable to flood damage when channels got choked and the water created a new channel through existing development.

In terms of historical management, Plymouth is interesting because there has been less management of the mountain streams themselves due to the restricted nature of the river channels above the valley floor; however, the Black River has been moved historically in various locations to accommodate road construction (Todd Menees, personal communication). In most cases, these mountain streams are less predictable and more dynamic than the larger rivers in the less confined and shallower slopes of the valley floor. Their unpredictability and velocity proved to be a major hazard during Tropical Storm Irene, far different from the erosion and inundation flood damage experienced along bottom lands of the Upper White Valley in the town of Rochester, the site of our other case study.

Rochester

Rochester is of particular interest as the town is a good model for documenting river management practices, as well as the damage of significant flood events. Rochester is located in a narrow agricultural valley, and the White River is easily visible in aerial photographs. Furthermore, visual evidence of Irene flood damage in Rochester in these photographs is significant, and evidence of historical channel migration is often visible in the fields themselves. Significant work has been done in identifying future management sites along the Upper White (Ruddell et al. 2007), with an emphasis on passive restoration and creating access to floodplains. Many of these management proposals conflict with current agricultural land use as well as with businesses linked to the tourism and hospitality industry.

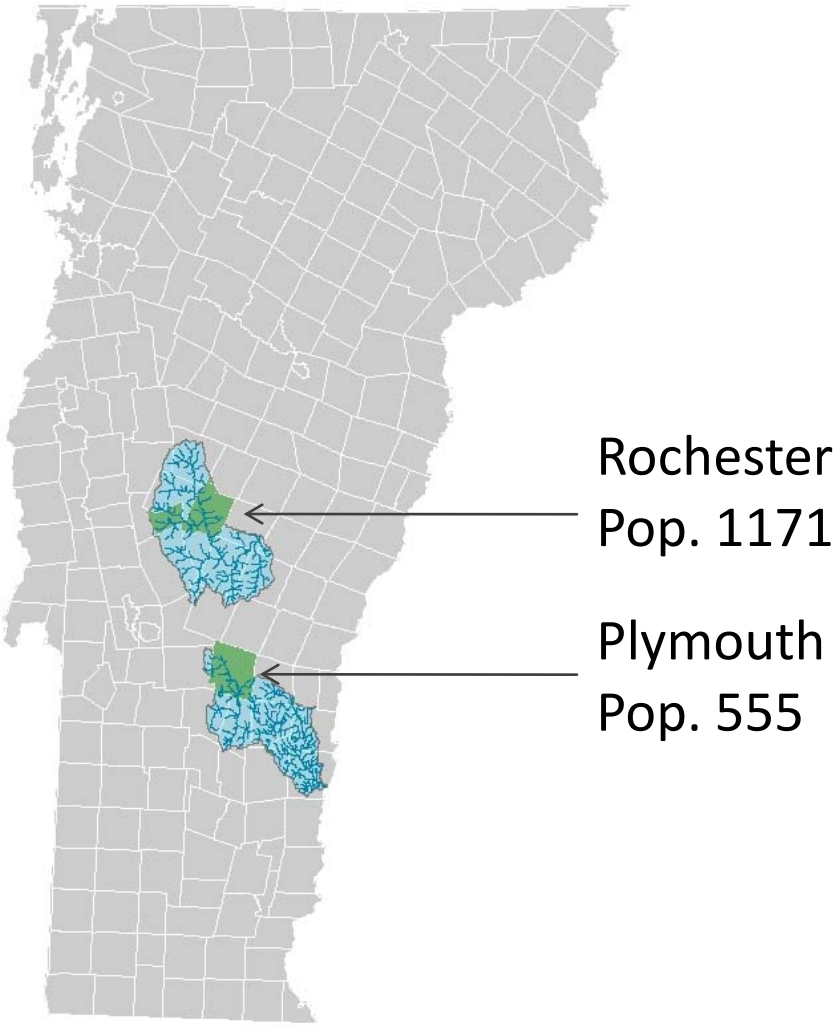


Figure 4. Locating Rochester and Plymouth in Vermont. Both towns are located in Windsor County; Rochester is in the Upper White River watershed, while Plymouth is located in the Black River watershed.

Given the groundwork that has been done in establishing the geomorphic regimes of these towns, as well as the two distinct flood regimes that they represent, Rochester and Plymouth together provide a unique opportunity to analyze site-specific issues pertaining to the costs and benefits of balancing geomorphic-minded management regimes with human infrastructure.

B. Cost-Benefit Analysis: A Framework for Future River Management Decisions?

A cost-benefit analysis (CBA) may offer a useful way to value and weigh the various factors which affect future management decisions; however, a cost-benefit analysis may provide

a distorted or simplified picture of the situation based on limited representation of economic, social and ecological values. All three values are highly variable and difficult to define in monetary terms. Both the variables and specific monetary costs used in the analysis as well as the role of the cost-benefit analysis in the decision making process are of critical importance.

The Difficulty of a CBA Approach in River Management

In the context of making future river management decisions, the various costs and benefits become very difficult to quantify. A river is a dynamic and responsive system, where management in one place can have unintended or unknown downstream effects. These effects are not only difficult to monitor but they are also extremely difficult to measure. Moreover, there is a scale disparity: a river may span hundreds of miles, while those who actively manage and incur the impacts of that management often only occupy a small portion of this expanse. This disconnect between micro-river management in the macro-river system only complicates the situation further. Suppose a river was diverted from a farmer's field upstream, providing economic benefits to the farmer in the form of an increase in productive land area. This same action which benefits the farmer may cause long-term devastation downstream. These complex dynamics make a fully-inclusive cost-benefit analysis extremely difficult. Further complicating the issue is the fact that all projects are incredibly site-specific: variables such as the bank height and steepness, the location of the quarry that the rip-rap is extracted from, and whether or not the town uses their own equipment can all have a significant impact on the project details and therefore the cost (Todd Menees and Ethan Swift, personal communication). As a result, something as deceptively simple as installing rip-rap on a bank can range in price from $40 - $250 per linear foot depending on the bank height and the thickness of the armoring (for a more complete picture of the variability of estimates depending on site-specific circumstances, see Appendix B). Therefore, to fully weigh the costs and benefits of management at the societal scale, the river would need to be analyzed in its full extent, where all factors, such the relationship between upstream and downstream management practices, could be incorporated.

Despite the difficulties, several government agencies have attempted to provide economic values for river systems. The California Department of Water Resources (CA DWR) developed an economic framework for determining the value of multi-objective floodplain management proposals (Multi-Objective Approaches to Floodplain Management on a Watershed Basis). This project arose in response to river management practices that are based solely on immediate

financial concerns. The CA DWR introduced methods for "valuing natural floodplain environmental *and* societal benefits" (ibid). Also noteworthy, this project included recommendations for how to assign benefits for structures removed from floodplains, something that is closely related to the FEMA buyout program in Vermont**.** This FEMA program offers buyouts to property owners who live in vulnerable areas that are severely and repeatedly damaged or destroyed by high water events. The applications for a buyout are screened and applied for by the local town offices. The buyout is supposed to be covered 75% by the federal government and the remaining 25% by the town (Kristen Underwood, personal communication). Eligibility for FEMA buyouts is limited to property owners who have experienced catastrophic damage.

The first round of applications in February 2012 was reserved for homes which had experienced greater than 50% loss. Homeowners applying for FEMA assistance must meet the BCA (Benefit-Cost Analysis) threshold established by FEMA that is calculated by a FEMA-specific software program. According to personal conservations Kristen Underwood had with Vermont residents, a home that has sustained $5,000-10,000 losses in each of three flood events over the past 10 years would likely *not* meet the BCA thresholds and therefore would *not* rank high enough for FEMA funding. There are different qualifications for a FEMA buyout. There is "Repetitive Loss Eligibility" for which the homeowner needs to have experienced repeated losses of 50% or greater. This is an unprecedented situation: there is only *one* house in the state that currently qualifies. There is also "Imminent Risk Eligibility" which is described by local residents as being a house hanging over the bank about to fall into a river.

The new statewide Hazard Mitigation Plan (HMP) will be including language to prioritize and establish procedures to buy out homes that are in the floodplain and are not currently eligible for FEMA buyout programs. There is potential for new Vermont legislation that would create a state fund that would be solely used to purchase homes in floodplains as a means to avoid erosion hazard losses. As it stands now, a home has to be destroyed or nearly destroyed in order to be eligible for a buyout under FEMA (Kristen Underwood, personal communication). For more information on FEMA and HMP refer to Chapter 3, Section IV.

Another aspect of cost-benefit analyses that is still being researched is the concept of ecosystem services, or understanding and putting a value on services that natural systems provide, such as flood mitigation. Some of this work involves creating dollar values and markets

to bring these traditionally external values into the economic calculations of cost-benefit analyses. In King County, Washington State, researchers weighed flood hazard reduction services and flood mitigation services, as well as the avoided costs of flood-related damage as a result of these projects (Sweeden and Pittman, 2007). Many of the difficulties that we ran into in terms of time and information were mirrored in this report; while the report noted that there is a lack of research on the transfer of ecosystem services, the framework that it provided concerning both ecosystem services as well as avoided costs is a useful one. Within this framework, projects need not be confined to a cost-benefit analysis based solely on flood mitigation potential, and instead can also take into account other ecosystem services and external benefits.

Cost-Benefit Analysis: Providing Stakeholders with a Means to Weigh Management Strategies

Any flood mitigation strategy and the resulting projects need to weigh societal values and the impacts there to. CBA in financial terms can never internalize these subjective experiences. CBA is part of a broader process that must incorporate subjective experience in a way that allows all stakeholders to feel fairly represented regardless of the resultant outcome. To this end, we have generated a cost-benefit analysis for Liberty Hill Farm in Rochester, Vermont. As a farm in a Vermont river valley floodplain, this location provides an ideal study because it is representative of many similar sites statewide.

Why Care About Weighing Costs and Benefits Now?

Tropical Storm Irene exposed the vulnerability of Vermont towns to flood hazards. Additionally, individuals, towns, and counties are currently rethinking their strategies concerning rivers, and are actively engaging with various government programs to change current practices. This is an opportune moment for change. Providing incentives and evidence that alternative river management practices can be individually, socially, ecologically and economically beneficial might encourage more sustainable river management in Vermont.

Valuing River Management Costs and Benefits: Qualitative and Quantitative Factors

As previously mentioned, cost-benefit analysis is a difficult undertaking for river management practices. There are short- and long-term, individual and social, upstream and downstream, quantitative and qualitative costs and benefits associated with river management. We have tried to break down all of the aspects of river management practices, both traditional

and alternative, in the tables below. Distinguishing between the intended and unintended effects of each practice, along with the costs and benefits, provides an accessible framework for understanding river management practices in their entirety.

Traditional River Management Practices

Rip-rap (Bank Armoring)

Intended Effects	**Unintended Effects**	**Individual benefit**	**Quantitative/ Qualitative?**	**Individual Cost**	**Quantitative/ Qualitative?**
Structural support, armors bank and prevents erosion	Reduces habitat for local species, creates barriers between land and river (less improvement of water quality). Prevents lateral migration (form of channel evolution), can localize kinetic energy of river, and reduces riparian succession processes	Protection of personal property, reduces erosion	Qualitative	$40 - $250/ linear foot*	Quantitative
		Social Benefit	**Quantitative/ Qualitative?**	**Social Cost**	**Quantitative/ Qualitative?**
		Protects public transportation infrastructure	Qualitative	Downstream effects on property and infrastructure: more likely to be damaged in future floods. Ongoing maintenance is costly.	Qualitative

*Depends on the height of bank and thickness of armoring.

Dredging (Excavation)

Intended Effects	**Unintended Effects**	**Individual Benefit**	**Quantitative/ Qualitative?**	**Individual Cost**	**Quantitative/ Qualitative?**
Alleviates inundation and blockage after floods. "Reclaims" gravel deposited in rivers by a flood.	Removes substrate that slows river flow causing higher velocity water movement in future floods. Deepens streambed. Removes material that create riffles (aquatic habitat loss).	Lowers water levels and visible "recovery" of rivers.	Qualitative	Approximately $200/ hour & $1000 - $2000/ day	Quantitative
		Social Benefit	**Quantitative/ Qualitative?**	**Social Cost**	**Quantitative/ Qualitative?**
		Relief from inundation after high water event. Gravel extracted can provide materials for infrastructure construction.	Qualitative	Increased river velocity leads to greater erosion. Rivers gain *power* through channelization and will remove/ damage management investments.	Qualitative

Straightening/Berming

Intended Effects	Unintended Effects	Individual Benefit	Quantitative/ Qualitative?	Individual Cost	Quantitative/ Qualitative?
Allocates river to temporarily convenient locations so desired areas can be developed (private property) and public infrastructure can be built in preferred locations.	Increases river slope and velocity. Decreased capability to improve water quality. Rivers become disconnected from flood plains (where sediment and nutrients are normally captured) so greater deposits in receiving waters. Rivers restricted from meandering. Loss of pools and riffles (loss of aquatic habitat). Riparian habitats lost.	Protection of personal property, reduces erosion	Qualitative	Approximately $200/ hour & $1000 - $2000/ day	Quantitative
		Social Benefit	**Quantitative/ Qualitative?**	**Social Cost**	**Quantitative/ Qualitative?**
		Human control over river location is convenient.	Qualitative	Downstream areas become more vulnerable. Flow, sediment, and debris sent downstream because not caught by flood plains or bends in river.	Qualitative

Alternative River Management Practices

There are three main alternative strategies associated with the mitigation of river damage. These three avenues are land-based programs that attempt to relocate individuals residing in flood-prone areas through government buyouts, zoning laws that discourage or prevent future development in floodplains, and conservation easements that provide financial assistance to those who have repeatedly experienced flood-related damage to their agricultural land and decide to remove their lands from production, allowing the river to take its natural course.

Property Buyouts

Intended Effects	**Unintended Effects**	**Individual Benefit**	**Quantitative/ Qualitative?**	**Individual Cost**	**Quantitative/ Qualitative?**
Relocating residents in flood-prone areas who have experienced severe and repeat property damage (>50%).	Removing individuals from their homes and communities.	Less future costs repairing property after flood events.	Quantitative (case-by-case)	Separation from home and (if farmland) from livelihood.	Qualitative and Quantitative
		Social Benefit	**Quantitative/ Qualitative?**	**Social Cost**	**Quantitative/ Qualitative?**
		Also decreased future accumulative costs assisting residents with property and land repair (long-term).	Quantitative (town, state, and federal level)	Government must invest in these repeatedly damaged properties and cover the costs of the buyout.	Quantitative: 75% Property value - (FEMA) 25% Property value - (Town)

Zoning Regulations

Intended Effects	**Unintended Effects**	**Individual Benefit**	**Quantitative/ Qualitative?**	**Individual Cost**	**Quantitative/ Qualitative?**
Prevent and limit future development in floodplain.	Restricts development in lands near rivers which are usually the most fertile and at the bottom of the valley where the terrain is the most flat.	Drastically reduces the probability of homes and other structures being built in hazardous areas.	Quantitative (preventative)	Restricts farming development in fertile areas and prevents structures from being built along scenic river paths.	Quantitative and Qualitative
		Social Benefit	**Quantitative/ Qualitative?**	**Social Cost**	**Quantitative/ Qualitative?**
		Lowers potential future costs for assistance programs that would have needed to help residents who lived in the floodplain.	Quantitative (town, state, and federal level)	Government must pass legislation that would likely result in overall decreases in agricultural production and potential tourism profits. Zoning regulations might also be contested by local residents: discontent.	Quantitative and Qualitative

Conservation Easements

Intended Effects	Unintended Effects	Individual benefit	Quantitative/ Qualitative?	Individual Cost	Quantitative/ Qualitative?
Remove existing agricultural land from production to allow the river to naturally meander and possibly reclaim land.	Lowers agricultural capacity and thus farmers' livelihood.	Financial reimbursement by government programs for allowing conservation easements	Quantitative (case-by-case)	Restricts farming and lower agricultural profits.	Quantitative (case-by-case)
		Social Benefit	**Quantitative/ Qualitative?**	**Social Cost**	**Quantitative/ Qualitative?**
		Allowing the river to meander, deposit and potentially flood the floodplain will lower down-stream effects. Velocity and debris loads will decrease.	Qualitative and Quantitative (ecosystem services)	Government programs must reimburse farmers who put these conservation easements in place.	Quantitative

IV. Case Studies

We chose to develop case studies for 2 sites in Rochester Vermont, and 2 in Plymouth Vermont. These sites represent different geomorphic settings, land use (farm versus village), property ownership (one owner versus many) and historical management practices. The sites in Rochester both were damaged in Irene from river inundation in the valley bottom. The sites in Plymouth both were damaged from the alluvial fan condition given their location at the foot of the Green Mountains.

Case Study Selection

Liberty Hill Farm, Rochester, VT: This site is a productive agricultural operation located in the floodplain of the Upper White River. The site was chosen because it is an example of a common river-human conflict in Vermont, and was the first project listed in the Stream Geomorphic Assessment for the Upper White River. The case study includes historic river channel migration mapping, historic river channel analysis, and a cost-benefit analysis.

Cobble Hill Stable, Rochester, VT: This site is another agricultural operation located in the Upper White River floodplain. The site was chosen because of the highly visible meander scars in the field, providing clear evidence of the historical path of the river and the scope of human management of the river. The case study includes historical river channel migration mapping including meander scar locations, a 3-D visualization of the historic river channel based on the meander scars in the field, and historical river channel analysis.

Plymouth Notch, Plymouth VT: This site is a small village located within the town of Plymouth. The site was selected because the damage at this location was not caused by inundation flooding as with the case studies above, but instead by a small mountain stream—Great Roaring Brook—carving a new channel in the alluvial fan that several homes are built on. The case study includes a 3-D visualization of the geomorphology at this site and a historical management analysis.

Pingree Sugar Shack, Plymouth VT: This site contains a sugar shack located at the base of another alluvial fan. The damage incurred from Tropical Storm Irene was several hundred feet away from the Black River, located in the valley floor. This property has a single owner, and they experienced a total loss of the sugar shack. The case study includes historical river channel mapping and an analysis of historical management.

A. Liberty Hill Farm: Reach 20, Upper White River, Rochester VT

Historical River Channel Analysis

According to the Upper White River Corridor plan, Reach 20 offers the first relatively unrestricted access to the floodplain after an extensive erosional stretch of river upstream. This assessment is consistent with observations of the damage to Liberty Hill Farm from Tropical Storm Irene: the entire farm field and golf course to the south were inundated during the flood and sustained significant sedimentation, and historical sedimentation has been noted in the Stream Geomorphic Assessment. Historically, 90% of Reach 20 has been straightened, with 76% of the reach still being actively straightened as of 2004.

The present course of the river is remarkably similar to that of 1939, with the exception of a steady downstream migration of the meander at the southern portion of Bob and Beth

Kennett's (property ownders) home farm. There has been extensive rip-rap used, as seen along the northern edge of the White River Golf Course.

Figure 5. Rip-rap along the northern extent of the White River Golf Course. Photo Mark Little

Aerial photo analysis shows that this bank was moved upstream between the floods of 1978 and 2011. Based on the Stream Geomorphic Assessment and River Corridor Plan, this section of the White River exhibits a high sensitivity to future river channel migration, and therefore preserving the existing river channel will require large investments in management infrastructure. Given recent lack of funding from Natural Resources Conservation Service (NRCS) for such management practices, most of these costs will be passed on to the Kennetts. The stream still has access to the floodplain in the form of the cultivated fields in this segment, although bank incision and recent down cutting of the river channel could restrict access to the floodplain in the near future, further encouraging channel migration. Large sections of the bank have been planted with trees, although generally buffer widths are 25 feet or less. With cooperation from the U.S. Fish and Wildlife Service, attenuation assets and revetments (Appendix A) were installed along the northern westward traveling meander to encourage sediment deposition and prevent further bank incision and field loss. Unfortunately, the flooding following Tropical Storm Irene dislodged both the revetments and many of the buffer plantings.

Figure 6a. Liberty Hill Farm aerial image before Irene. Basemap source: NAIP 2009.

Figure 6b. Liberty Hill Fram after Irene. Note significant sedimentation on parts of the field on the inside of the meander bend. Basemap source: Google Earth.

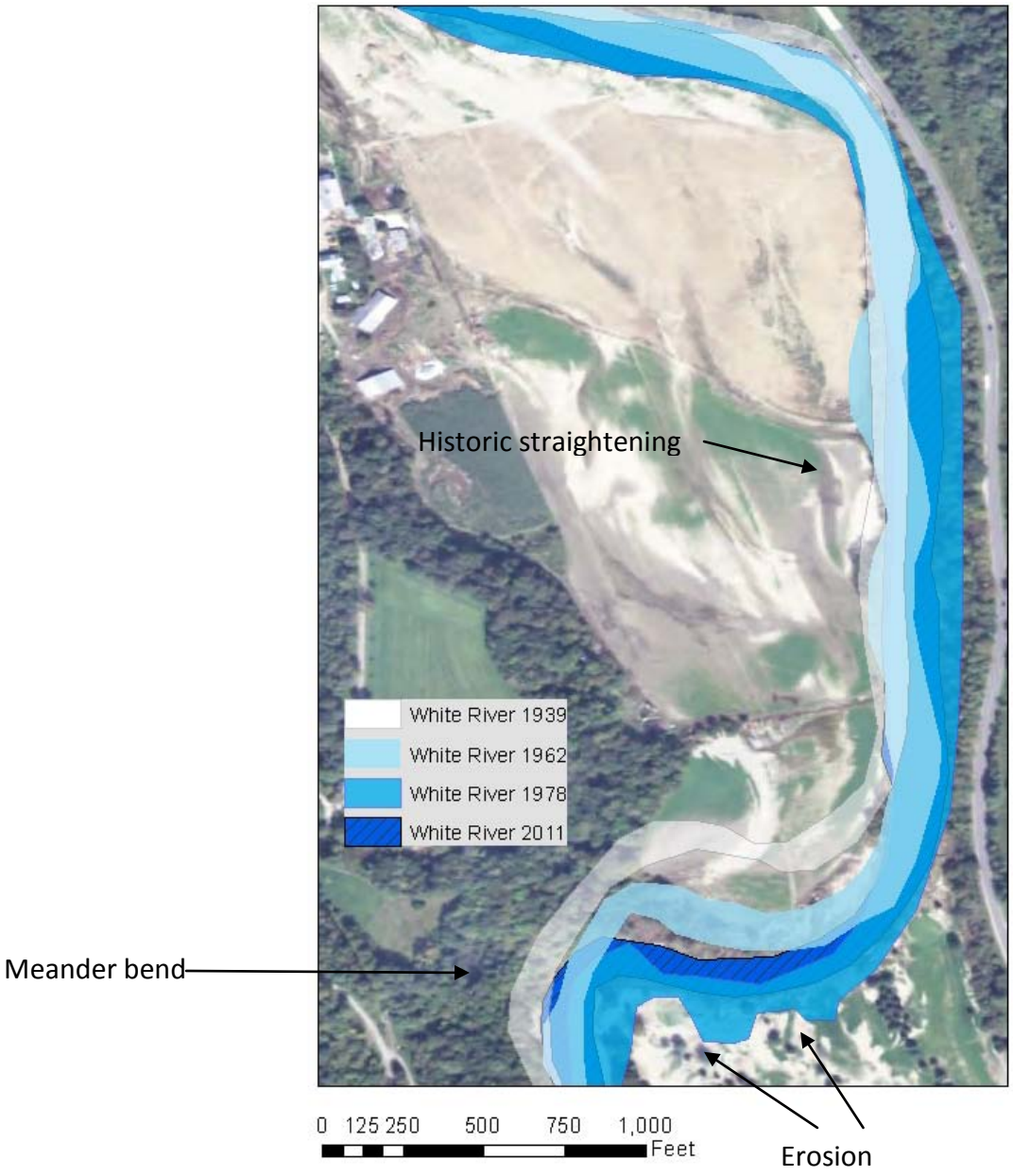


Figure 6c. Liberty Hill Farm, Rochester VT. A portion of reach R20 documenting the historical river channel migration through the river valley. Note historical downstream migration of the meander bend after historical straightening on the upstream segment. Between 1939 and 1962, you can begin to see the development of a meander, but it is straightened again in 1978. After flooding in 1978, you can see erosion pockets forming that disappear in subsequent years. Note the harshness of the curve developing as the river attempts to migrate downstream, but is blocked by downstream infrastructure protected using bank stabilization and riprap. Basemap from 2011.Georeferenced. Orthophoto sources: USDA NRCS National Geospatial Management Center, Google Earth satellite imagery.

Liberty Hill Cost-Benefit Analysis

Liberty Hill Farm is 130 acres in area, with a property value of $393,200 (Rochester Tax Records). The farm sustained significant damage during Irene, including crop losses and a significant decrease in farm field productivity. The farm is currently under consideration for a conservation easement, which would remove land from productive use and allow the land to be naturally reclaimed by the meandering course of the river. Previously, such migration had been prevented by management practices including rip-rap armoring. We were unable to determine how often or intensely the river was and continues to be managed at Liberty Hill Farm, as no site-specific records of management are kept. Instead, for the purposes of our analysis we have assumed a rip-rap cost of $250 per linear foot. Liberty Hill Farm has 210 feet of rip-rap installed, for a total cost of $52,500. We cannot assume that 100% of this cost will be incurred again if the rip-rap requires future maintenance after a high water event like Tropical Storm Irene; however, future damage to the bank armoring is likely.

The damage from Irene to Liberty Hill Farm was debilitating, with the most significant damage to the agricultural fields themselves. Some of the farm's structures were affected by the storm, but our primary focus will be on the productive land rendered unusable by Irene. We have decided to weigh the value of the farm's productive land against taking that land out of production through a conservation easement. During Irene, Liberty Hill Farm lost 50 acres of corn valued at $2.28 per bushel. Assuming a rate of 300 bushels per acre, this yields a total loss of $34,200. Given the amount of sediment deposited onto the land, it is highly likely that the lands will continue to be unproductive for at least a few years, leading to continued economic losses for the Liberty Hill Farm. One possible conservation easement would designate all of the farm's land that is in the Fluvial Erosion Hazard (FEH) Zone as labeled by the Stream Geomorphic Assessment into an easement—an option that would essentially include all of the productive land at Liberty Hill Farm. The following table illustrates the annual loss of income due to removing productive land from use for Liberty Hill Farm, based on the extent of the easement buffer around the river.

Easement width around Upper White River (feet)	50	100	150	200	FEH
Acres of Land Affected	7.98	26.63	48.40	70.33	151.47
$ Value of Corn (annually)	5,461	18,218	33,106	48,104	103,602

Given these values, it would seem apparent that the one-time cost of $52,000 for rip-rap provides greater benefits in the form of continued revenues from productive land (a loss of $103,600 in annual revenues versus a $52,000 one-time cost). However, weighing these two considerations alone disregards the downstream implications for the rip-rap as discussed earlier and the potential for future maintenance costs to the rip-rap, which has the potential to be significant if storms of Irene's magnitude become more frequent. While we cannot fully quantify the downstream social cost resulting from upstream rip-rap, the increased river velocity and restrictions to the river's natural depositional functions caused by bank armoring undoubtedly create community costs downstream.

A major confounding factor to any cost-benefit analysis is that there is no way to determine whether devastation is caused merely because structures or land are damaged through a natural flooding regime alone, or whether that damage has been exacerbated by upstream management practices. Determining the effects of upstream management would require a controlled experiment, in which the same volume of rain would fall on an area with management, and then the same area without management. This is entirely unfeasible, so we must rely on river science, which argues that these management techniques cause increased damage during flood events, regardless of the natural channel conditions present.

In the case of Liberty Hill Farm, the immediate downstream devastation from Irene is clear. The White River golf course located just downstream of Liberty Hill Farm was also devastated by sedimentation.

Figure 7. White River Golf Course, immediately south of Liberty Hill Farm. Photo source: Google Earth satellite imagery.

The golf course sustained $175,000 of damage in the wake of Irene (Pete McGowan, personal communication). In this context, the $52,000 spent on rip-rap in an effort to avoid annual losses of $34,200 begins to seem less cost-effective given the potential downstream affects. That same $52,000 in rip-rap *may* have resulted in or at least contributed to the $175,000 in downstream property damage at the golf course—but because it is impossible to measure that contribution, we cannot incorporate this possibility directly into our analysis.

Simple cost-benefit analyses cannot, and should not, be the only factor in decisions about whether to put land into easements or continue production as before. We must emphasize that any cost-benefit analysis is only one part of a process that places all stakeholders within the decision making process, and creates an atmosphere in which all stakeholders feel they can adequately represent their interests (David Mears, personal communication). In many ways, the above cold calculus of financial cost-benefit analyses for Liberty Hill Farm ignore larger concerns, such as the social value of the working landscape, the ecological value of local food, and the rural character of the Vermont landscape in the tourism industry. The Kennett's history as founding members of the White River Partnership and their riparian planting efforts

demonstrate their strong willingness to work towards river health. Continued cooperation with the River Management Program will help to illustrate the considerations and choices individuals need to make over the long term when balancing river health with agricultural viability, both of which are a priority for the health of Vermont's larger community.

B. Cobble Hill Stable: Reach 22, Upper White River, Rochester VT

Historical River Channel Analysis

The SGA performed on the Upper White River documents significant levels of river management on Reach R22: historically, 100% of the reach has been straightened, and 83% is still maintained in a straightened condition. Our overlay analysis of historical orthographic photos from 1938 to 2011 demonstrates that the river has experienced minimal migration over the past 70 years, with few deviations from this route of more than 250 feet. Meander scars are present in the agricultural field throughout this period, and can be seen as early as 1938 (Figure 8a). These meander scars are roughly 800 feet from the current river course. This indicates that the historical river management to maintain the river and keep it from re-establishing a meander pattern has been present for at least 70 years. It is highly likely that the historical straightening of reach R22 has resulted in downstream effects during significant flood events.

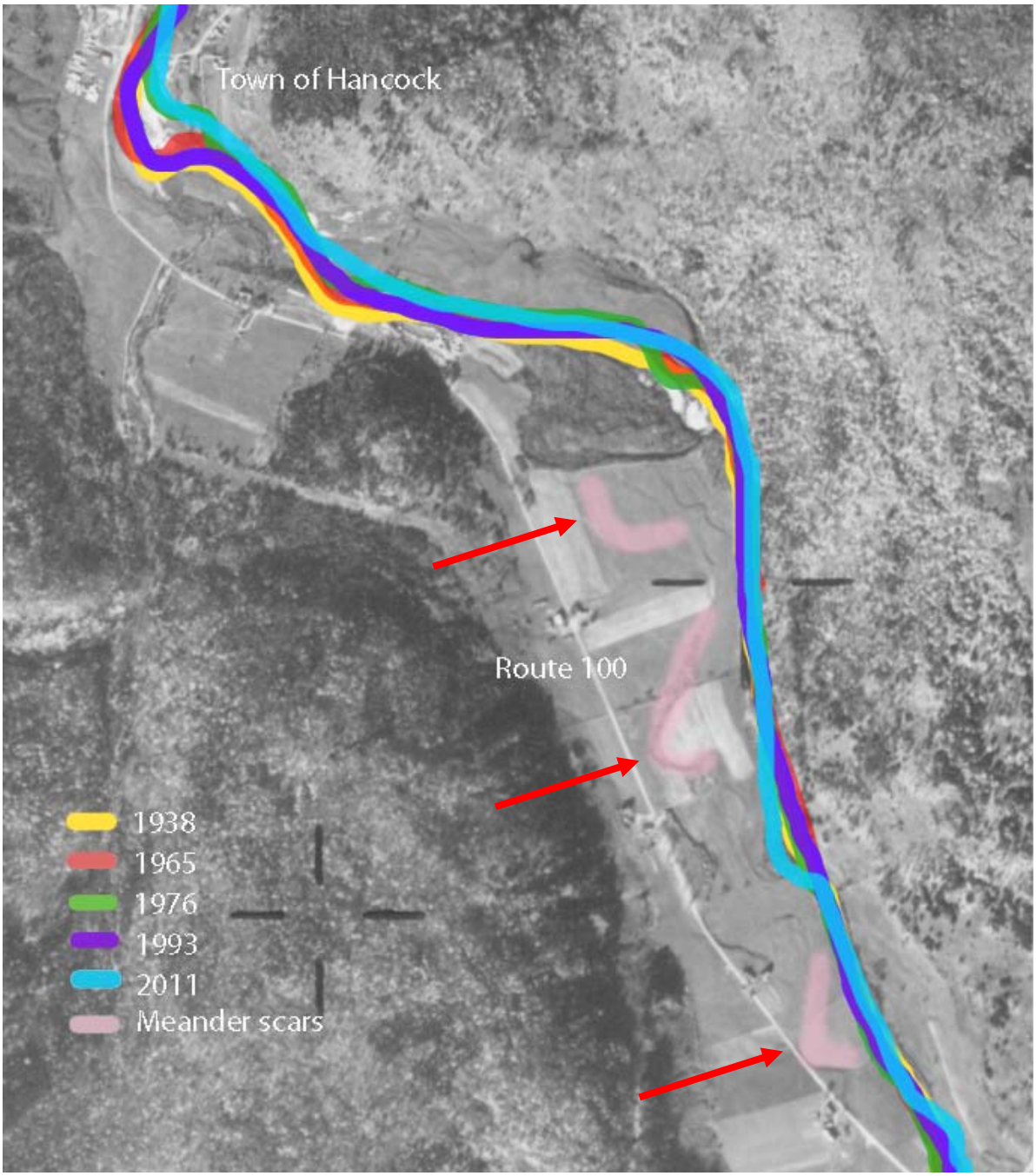


Figure 8a. Upper White River, South of Hancock. This map displays a portion of Reach R22 documenting the historical river migration and historical meander paths through current agricultural fields. Red arrows highlight meander scars that suggest that historically the river once meandered through those locations. Basemap from 1938. Orthophoto source: USDA NRCS National Geospatial Management Center.

Historical River Channel Re-creation

At Cobble Hill Stable, Vermonters have provided room for the agricultural field and Route 100, the result of many years of management practices used to keep the river in place. Based on this recreation, it is clear that the river once meandered through the current agricultural field (Figures 8b and 8c). Without continuous river management the river is likely to return to its historic location within the valley floor. This possibility presents a serious challenge to any floodplain development, as moving and holding the river to the valley wall through continuous management works against the inherent hydrology of the river system.

Figure 8b. Cobble Hill Stable, Rochester VT, 2009. The river can be seen pushed up against the valley wall.

Figure 8c. Cobble Hill Stable, Rochester VT, Historical Recreation. This recreation is based on the meander scar patterns present in the landscape (see Figure 8a). Basemap image: Google Earth.

C. Plymouth Notch: Black River, Plymouth, VT

Plymouth Notch is a small village within the town of Plymouth. Unlike the previous two case studies, the flood damage that occurred in Plymouth Notch was not the result of river valley inundation; instead, the damage was caused by a steep mountain tributary bottoming out into an alluvial fan that under normal circumstances appears unlikely to flood. However, appearances are deceptive, and because much of the village is situated on this alluvial fan, there is high future potential for flood damages. In contrast to inundation flood patterns, alluvial fan dynamics are poorly understood and much more attention needs to be paid to monitoring alluvial fan conditions in the context of human development. Currently, Stream Geomorphic Assessments focus primarily on larger streams on valley floors due to a lack of resources and funding to assess these mountain tributaries (Kristen Underwood, personal communication). This is especially true because alluvial fans often exist outside of the FEMA-designated flood zones, putting any development within the alluvial fan zone at increased risk because of the lack of awareness surrounding this condition.

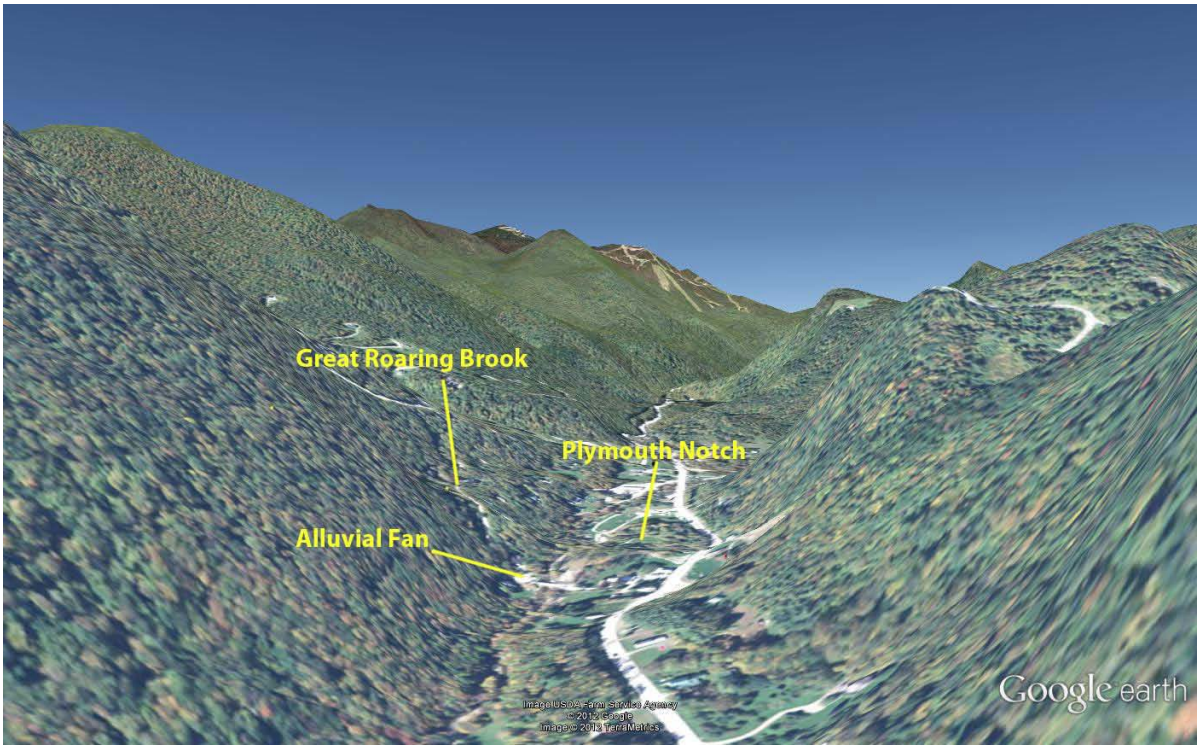


Figure 9. Plymouth Notch along Route 100.

D. Pingree Sugar Shack: Near Money Brook, Plymouth, VT

Historic River Channel Analysis

Much of the damage to the Pingree Sugar Shack and surrounding development was not caused by inundation from the Black River (which, as can been seen from Figure 8a, has not moved significantly from its current location over the last 70 years). Instead, most of the damage came from Money Brook, which in this location has formed an alluvial fan similar to the one discussed in the previous case study for Plymouth Notch. The property is owned by a single person, so a buyout becomes a much less complicated proposition. The Pingree Sugar Shack property is valued at $210,120 (Plymouth Tax Data). The sugar shack structure was completely destroyed, and the field currently sits under a thick layer of rocky debris and sediment. We believe the sugar shack is an ideal candidate for a buyout, as the likelihood of another alluvial-fan related flood is high (For images of historic and post-Irene damage, see Appendix C).

Figure 10. Historic Channel Migration of Black River at Pingree Sugar Shack, Plymouth, VT. Basemap: 2009. Georeferenced. Sources: USDA NRCS National Geospatial Management Center, Google Earth.

V. Conclusion

In our case study sites of Liberty Hill Farm and Cobble Hill Stable in Rochester, and those of Plymouth Notch and Pingree Sugar Shack near Money Brook in Plymouth, overlaying historic orthorectified photos from 1938 to 2011 demonstrates that the Upper White River and the Black River have experienced minimal migration, with few deviations over 250 feet. According to the Upper White River Corridor Plan, the Upper White River at both Liberty Hill Farm and Cobble Hill Stable has been previously straightened. As early as 1938, meander scars are present in the adjacent agricultural field, indicating that the historical river management to maintain the river and keep it from re-establishing a meander pattern has been present for at least 70 years.

As a result of the historical straightening that presumably has downstream effects during flood events, our group weighed the various factors of future management decisions at Liberty Hill Farm through a cost-benefit framework. With almost no records on the specific locations and costs of practices, we considered the value of productive land against a conservation easement. Although the one-time cost of $52,000 for installing 210 feet of rip-rap provides greater benefits in the form of continued revenues, the social cost of the rip-rap on downstream properties must also be considered. Unable to give a monetary estimate of the social cost and unable to prove whether the downstream devastation was a direct effect of the rip-rap or the result of natural forces, we relied on river science, which argues that these management techniques increase damage during flood events. Pete McGowan, the owner of the White River Golf Club, located downstream of Liberty Hill Farm, reported that the golf course sustained damages of $175,000 in property losses after Irene. We conclude that management practices need to consider how the upstream management may result in worsening damages downstream.

Throughout the process of this project, our general recommendations include more cooperation between state agencies and more incentives for best river management practices. We also suggest more active outreach for farmers and more training for Vermont Agency of Transportation on river geomorphology. Within the Vermont Department of Environmental Conservation, river engineers are understaffed. A single-digit number of them are responsible for approving stream alternation permits for any repairs for the entire state. As part of the permitting process, our group recommends recordkeeping on the costs and specific locations of river management practices for towns. Although the costs may vary and are case-specific, with

enough data, this information could still be used to assess river management practices in other similar locations and can be digitized for future geomorphic assessments.

VI. Bibliography

Assembly of the Gilbert F. White National Flood Policy Forum. 2004. "Reducing flood losses: Is the 1% flood standard sufficient?" *Association of State Flood Plain Managers.*

Bergstrom, J.C., J.R. Stoll, J.P. Titre, and V.L. Wright. 1990. "Economic value of wetlands-based recreation." *Ecological Economics* 2(2): 129-147.

Brander, L.M., R.J.G.M. Florax, and J.E. Vermaat. 2006. "The empirics of wetland valuation: a comprehensive summary and a meta-analysis of the literature." *Environmental and Resource Economics* 33:223–50.

Brooker, M.P. 1985. "The ecological effects of channelization." *The Geographical Journal* 15(1): 63-69.

Brown, A.V., M.M. Lyttle, and K.B. Brown. 1998. "Impacts of gravel mining on gravel bed streams." *Transactions of the American Fisheries Society* 127: 979-994.

California Department of Water Resources. 2005. "Multi-Objective Approaches to Floodplain Management on a Watershed Basis: Floodplain Management, Benefit and Cost Analysis Framework" (DRAFT).

Chen, Z.M., G.Q. Chen, B. Chen, J.B. Zhou, Z.F. Yang, and Y. Zhou. 2009. "Net ecosystem services value of wetland: environmental economic account." *Communications in Nonlinear Science and Numerical Simulation* 14(6): 2837-2843.

Department of Natural Resources. 2010. "Proposed Rules and Regulations for Regulator Floodplains in Colorado: Cost Benefit and Regulatory Analysis." *Colorado Department of Water Resources.*

Duffy, W.G. and S.N. Kahara. "Wetland ecosystem services in California's Central Valley and implications for the Wetland Reserve Program. *Ecological Applications* 21(3): S18 –S30.

EPA Region 7. 2005. "Stream channelization." Clean Water Act/Wetlands Program Section 404 Fact Sheet.

Fischenich, J.C. 2003. "Effects of riprap on riverine and riparian ecosystems." *Wetlands Regulatory Assistance Program,* Army Corps of Engineers.

Henzel, L. 2012. "Living in harmony with streams: a citizen's handbook to how streams work." Friends of the Winooski River, White River Natural Resources District, and Winooski Natural Resources Conservation District.

Jenkins, W.A., B.C. Murray, R.A. Kramer, and S.P. Faulkner. 2010. "Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley." *Ecological Economics* 69: 1051–1061.

Kline, M. 2010. "A Guide to River Corridor Easements." Department of Environmental Conservation, Vermont Agency of Natural Resources.

Kline, M. 2011. " River Corridor Management in a Flood Resilient Vermont." Department of Environmental Conservation, Vermont Agency of Natural Resources.

Kline, M. and B. Cahoon. 2010. "Protecting River Corridors in Vermont." *Journal of the American Water Resources Association* 1-10.

Kline, M., C. Alexander, S. Pomeroy, S. Jaquith, G. Springston, B. Cahoon, and L. Becker. 2004. "Remote sensing and field surveys techniques for conducting watershed and reach level assessments." Vermont Agency of Natural Resources.

Kondolf, G.M. 1997. "Hungry water: effects of dams and gravel mining on river channels." *Environmental Management* 21(4): 533-551.

McGlade, J and J.L. Weber. 2009. "Ecosystem accounting: climate change and governance of ecosystem services in Mediterranean coastal wetlands." *IOP Conference Series: Earth and Environmental Science.*

NOAA. 2011. "Preliminary Hurricane/Tropical Storm Irene weather summary for the North Country." National Weather Service Forecast Office, Burlington, VT.

Reckendorf, F. 2010. "Streambank erosion causes, and large woody material (LWM) solutions for streambank erosion and sediment reduction." 2nd Joint Federal Interagency Conference, Las Vegas, NV.

River Management Program. 2001. "Fluvial geomorphology: a foundation for watershed protection, management, and restoration." Department of Environmental Conservation, Vermont Agency of Natural Resources.

River Management Program. 2004. "River corridor protection and management, Fact Sheet 1." Department of Environmental Conservation, Vermont Agency of Natural Resources.

River Management Program. 2005. "River Dynamics 101 Fact Sheet." Department of Environmental Conservation, Vermont Agency of Natural Resources.

Ruddell, D., E. McLane, and B. Machin. 2007. "Upper White River Corridor Plan." White River Partnership.

Southern Windsor County Regional Planning Commission. 2010. "Phase 2 Stream Geomorphic

Assessment." Black River Watershed.

Swedeen, P. and J. Pittman. 2007. "An ecological and economic assessment of King County's flood hazard management plan." Earth Economics.

Thatcher, T., B. Swindell, and K. Boyd. 2009. "Yellowstone River Channel Migration Zone Mapping." Custer County Conservation District.

Zind, Steve. 2012. "State Recommends FEMA Buyouts For 99 Homes." Vermont Public Radio. Accessed at http://www.vpr.net/news_detail/94432/state-recommends-fema-buyouts-for-99-homes/.

Ortho Map Sources:

U.S. Department of Agriculture Natural Resources Conservation Service

U.S. Geological Survey (1938, 1962, 1978, 1995)

Google Earth (2011)

Appendix A: Glossary

Alluvial fan—A fan-shaped deposit of material at the place where a stream issues from a steep valley onto a plain or broad valley with a low slope.

Attenuation asset—A location at which the stream can deposit sediments and nutrients.

Avulsion—Any abrupt change in a stream's course, such as a stream changing course in an alluvial fan or a meander cut-off

Fluvial erosion hazard zone—An area especially vulnerable to fluvial erosion (major streambed and streambank erosion and/or the potential for avulsion) that are often a result of major physical stream channel adjustments that can occur during a flood event. This fluvial erosion becomes a hazard when it threatens human infrastructure.

Revetment—Structures that slow erosion; this can include bank armoring but generally refers to logs anchored next to banks that decrease local water velocity and can provide sediment deposition opportunities and create habitat for a variety of aquatic organisms.

River corridor—The stream and all of the lands adjacent to that stream within the belt formed by the lateral extent of the meander bends.

River corridor easement—The transfer of land use and channel management rights from the landowner to conservation organizations such as a land trust or a watershed organization. These easements are designed to protect natural river processes at key locations while providing compensation to landowners for the loss of productive land or development rights.

Sensitivity—The likelihood that a stream will respond to new disturbances such as management or flood events.

Stream geomorphic assessment—Extensive field surveys that are conducted to assess the condition of streams, providing information about historical and current physical processes (such as erosion) and how they fit into the broader context of the stream. This allows river managers to identify key locations such as where rivers are unstable and therefore undergoing changes to return to a stable state, historic floodplains that could be restored to reduce flooding impacts downstream, or historically unmanaged stretches of river that should be targeted for conservation.

Transport reach—A segment of stream whose velocity is high enough to transport sediments rather than deposit them; these are often characterized by bedrock streambeds that do not contribute to sediment levels in the stream and change very little in response to fluctuations in sediment load caused by flood events.

Definitions taken from: Kline et al. 2004, River Management Program 2005, Kline 2010, Reckendorf 2010, and Henzel 2012.

Appendix B: River Management Work Estimates

Source: Ethan Swift (personal communication)

River Management Work Estimates
DRAFT – April 26, 2012
For Planning Purposes Only[1]

Activity[2]

- **Trucking**
  - Rates – approximately $75 – $125/ hour
    - Depends on size of truck and distance of trucking

- **Excavation**
  - Rates – depends on size of equipment
    - Small excavator – approximately $85/ hour
    - Large excavator – approximately $200/hour

- **Grading** (could be excavator – bank shaping, ditching, or bulldozer)
  - Rates – depends on size of equipment
    - Small excavator/ dozer – approximately $75/ hour
    - Large excavator/ dozer – approximately $125

- **Combined** (i.e., trucking and excavation)
  - Rate – depends on size of equipment
    - Approximately $200/ hour and between $1000 and $2000/ day

Other Related Tasks

- Rip-rap (also known as bank armoring) – Approximately $40 - $250/ linear foot depending on the height of bank and thickness of armoring.

- Erosion Control – seeding, mulching, filter fabric, geo-textile, etc.
  - Rate – lump sum of $500 - $1000 per project
  - 1-day laborer – rate of $50/ hour

Project Examples

- Neshobe River excavation (use of 2 trucks and 1 small excavator) – 20 miles[2]
  - Rate - $120,000 for ~1500' of gravel excavation/ dredging of approximately 20,000 cubic yards. Bankfull removal of 4' (height) by 30' (width)
- Wardsboro bank stabilization

[1] Note – These estimates are mostly based on an hourly rate/ unit cost, or in some cases a lump sum, and should be used as a gross approximation based on the range of location, type of equipment, and time/ labor. Assume that this range will depend on these factors as well as others not identified in this summary.

[2] Assume that estimates are based on machine rate and operator. Assume a 10-hour day.

    - Rate of $18,000 for 500’ length * 7’ bank height (smaller stream)

- Addison landslide – road bank stabilization
    - Rate - $107,000 for 400’ * 25’ bank height

- Road reconstruction
    - Rate - $280,000 for 150 feet * 18’ bank height (1:1 slope bubbling out 25’ base width – at stream bed grade)

Other costs

- Culverts (based on 20 foot lengths) – purchased (installation cost is typically about 3 times the purchase price)
    - 3’ diameter ~ $500
    - 5’ diameter ~ $1000

Trucking examples (2006 rates):
If Town is providing project trucking, divide total quantity of rock and gravel by size of truck and round trip and loading time at quarry. For example:

200 cubic yards (CY) of rock
14 CY Town truck
1 hour round trip to quarry and loading time

200 CY/14 CY= 14.3 loads @1 hour per load= 14.3 hours of trucking @$50/hour = $750

Trucking rates based upon labor rate of $18 (hourly rate plus benefits) + rate to operate equipment $32 (based upon FEMA rates per specific equipment) = $50/hour

Labor and equipment rates can be listed separately or combined. For example above $50/per hour total for trucking or $18/hour labor + $32/hour for truck

Other examples (2006 rates need to be adjusted accordingly):

- Road fabric (recommended at most sites): non-woven fabric @ $0.85/LF
- Hydro-seeder material @ .02/sq ft plus rental and transport fees
  (Seed and mulch or hydro-seeding recommended at most sites)

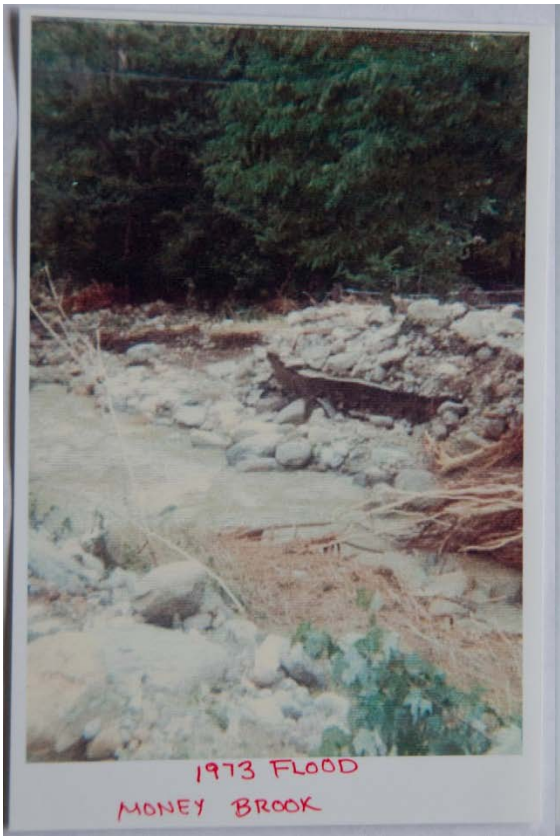
Example Cost Tables

Materials	**Quantity**	**Cost/unit**	**Total Cost**	**Notes**
62’ 15” culvert	1	$8.68/ft	$540	
Ditch stone	400 CY	$11.50/CY	$4,600	
Ditch fabric	1,200 ft	$.85/ft	$1,020	
Trucking	60 hours	$60/hour	$3,600	Town in-kind
Excavator Rental	1 week	$1,800/week	$1,800	
Excavator Delivery	Round trip	$350/flat rate	$350	
Seed and mulch	8,000 sq ft	.02/sf	$160	
Excavator Labor	40 hours	$25/hour	$1,000	Town in-kind
Other Labor	16 hours	$20/hour	$320	Town in-kind
Total cost			**$13,390**	
Total in-kind			**$4,920**	
Grant request			**$8,470**	

	Quantity	**Cost per Unit**	**Totals**
Ditch Stone (625 feet)	210 CY	$11/ CY	$2,310
Apron stone	14 CY	$16/CY	$224
48” culvert 41 ft	1	$2,700	$2,700
Culvert gravel	14 CY	$9/CY	$126
Excavator rental	5 days	$300/per day	$1,500
Hauling (14 cy truck)	17 hours	$50/per hour	$850
Grader	4 hours	$31/hour	$124
Total Labor (excluding trucking)	80 hours	$20/hour	$1,600
Total Grant Request			**$7,000**
Total In-Kind (26%)			**$2,434**
Project Total			**$9,434**

	Quantity	**Cost per Unit**	**Total**
Ditch Stone (1,175 LF)	392	$9/ CY	$3,528
Headwall Stone	28 CY	$15/ CY	$420
Filter Fabric	833	.80/sq yd	$668
Hydroseeder Material	5,000 sq ft	.02/sq ft	$100
36” Culvert & materials	1	$1,900	$1,900
Excavator	40 hours	$44/per hour	$1,760
Grader	2 hours	$31/per hour	$62
Hauling	30 hours	32/per hour	$960
Total Labor	160 hours	$22/hour	$3,520
Total Grant Request			**$7,000**
Total In-Kind (46%)			**$5,918**
Project Total			**$12,918**

Appendix C: Historic and Recent Images from Flooding in Plymouth, VT



2011 Flood, Sugar Shack along Rt. 100 by Money Brook

2011 Flood, Sugar Shack along Rt. 100 by Money Brook. Photo by Zach Doleac.

3. Documenting Repeat Flood Damage to Transportation Infrastructure

Morgan Boyles, Elizabeth Davis, Elissa Goeke, Sam Safran, Flora Weeks

I. Introduction

Tropical Storm Irene damaged and destroyed more than 500 miles of road and 200 bridges throughout Vermont. For many places, especially on the eastern side of the Green Mountains, Irene brought the highest floodwaters in recorded history. The widespread damage caused by Irene highlighted weaknesses in the state's transportation infrastructure (*Burlington Free Press* Feb 2012). Damages cut off more than a dozen rural communities from the outside world and shut down major transportation routes across the state. In the aftermath of this disaster it is of the utmost importance to consider ways to mitigate flood damage, especially in the face of changing climate regimes that will likely increase the frequency of high precipitation events in New England over the coming century (Stager and Thill 2010). The damage that Tropical Storm Irene brought to Vermont's transportation networks opened the opportunity to assess the strengths and weaknesses of the existing infrastructure in relation to future flooding events and to consider adaptive rebuilding strategies.

This project investigated repeat damage by: 1) assessing locations and extent of repeat damage to transportation infrastructure in several case study areas, 2) assessing the value of cost-benefit analyses for comparing current rebuilding patterns to other strategies, 3) looking at how climate projections may affect these strategies, and 4) compiling a list of policy avenues by which different rebuilding approaches can be implemented. We conducted a repeat damage assessment in the towns of Hancock, Rochester, and Plymouth and hope that our model process can be repeated in other locations throughout Vermont. For this repeat damage assessment, we first collected data on locations of damage to transportation infrastructure in major flood events. We then compiled these data into maps to visualize the locations of repeat damage. We used these maps in comparison with tentative fluvial erosion hazard zones to assess the potential success of fluvial erosion hazard zones in these areas. Along with location information, we accumulated data on the costs associated with each damage location and event.

We hope that the compilation of these data can help guide the towns of Hancock, Rochester, and Plymouth as they rebuild and plan for future flood events. In addition, we

believe this process can be repeated throughout the state as a way for towns and planning districts to assess varying recovery strategies.

We also examined climate change projections for Vermont in an attempt to determine the increased likelihood of flood events in the coming century. Projections of increased flood events have the power to increase pressure on policymakers and taxpayers to upgrade the existing infrastructure.

The final step in our project was to research current policy avenues available to assist with rebuilding and modifying existing infrastructure. We surveyed policies at the local, state, and federal levels that addressed access to funds for rerouting and buyouts. In addition to looking at government-funded policies, grant programs, and loans, we examined private sources of funding for rebuilding projects.

Throughout this process we consulted with community partners to guide the trajectory of our work, select study sites, network with contacts at specific study sites, and, most importantly, tailor our work to best serve the study communities. Our community partners include Ethan Swift, Watershed Coordinator at the Vermont Agency of Natural Resources, Kristen Underwood of South Mountain Consulting, and Joe Segale, Policy and Planning Manager for the Vermont Agency of Transportation.

This report begins with a brief history of flood damage to transportation infrastructure in Vermont and then focuses on the damage caused by Tropical Storm Irene. The discussion of Irene addresses the locations where Irene caused repeat damage and the policies used in the rebuilding process. Next, this chapter zooms in to our case study towns—Hancock, Rochester, and Plymouth—and presents maps and tables of repeat damage, as well as a discussion of the policies most relevant to rebuilding in these towns. This chapter concludes by examining how these case studies can be applied to other locations in Vermont and discussing the future implications of this work.

II. History

A. History of Transportation Infrastructure and its Relation to Flooding

European settlement of the rugged topography of the Green Mountains was inextricably connected to the region's river systems, which provided both transportation routes and hydropower. Road and rail networks sought routes of least topographic resistance and snaked up

river valleys. Where a dam could be built or where the river dropped over a falls, hydropower—first for sawmills and later for textiles and marble—was generated. For the past 150 to 200 years humans have altered nearly every component of Vermont's fluvial systems (Kline and Dolan 2010). People have extensively armored and channeled rivers to protect roads, farms that lie within the floodplain, and mills and other buildings that hug the water's edge in towns. There have also been drastic changes to the state's forests that greatly affect the characteristics of runoff during storms. These historic alterations to the riparian landscape and watersheds have greatly intensified the power of floods, which often damage areas settled on, or within dangerous proximity to, floodplains.

The legacy of these historical patterns of development has made the state highly vulnerable to the danger of floods. Of all natural hazards experienced in Vermont, flooding is the most frequent, damaging, and costly (Kline and Dolan 2010). Transportation is the sector hit the hardest, with the largest single source of flood losses in terms of cost as well as the number of people affected. Flood damage to transportation infrastructure is an extremely important issue because Vermont remains one of the most rural states in the nation, with more than sixty six percent of its population depending on rural roads to access basic amenities (USDA 2012).

The network of roads that supports Vermont's rural population relies heavily on town roads. Of the 14,000 miles of road in Vermont, 20% are maintained by the Vermont Agency of Transportation while the remaining 80% are maintained by towns (VTrans 2006). Floods have had a strong role in shaping the development of the state's road network, most notably after the 1927 flood, which washed out more than 1,200 bridges (Clifford and Clifford 2007). Much of the reconstruction of roads after floods has been based on the necessity to quickly reopen transportation routes and on the limits of town budgets. For this reason roads and bridges have been repeatedly rebuilt in the same areas vulnerable to repeat damage. This also means that floods pose a tremendous liability to town budgets.

B. Major Floods in Vermont's History

Vermont is well known for its highly variable and often extreme weather that can bring flood conditions. Though this mountainous state is landlocked Vermont receives, substantial moisture from the Atlantic Ocean, the Great Lakes, and the Gulf of Mexico (USGS 1989). Year-round precipitation ranges from an annual average of 36" in the Champlain Valley to over 68" in the Green Mountains (NOAA 2011). Major flooding may occur at any time of the year. Most

flooding occurs in the spring, when runoff combines with heavy rainfall, and in the fall, when wet tropical air masses can collide with the mountains. During the winter months ice jams can also occasionally cause major flooding.

Many of Vermont's watersheds are highly prone to rapid runoff and flash flooding. Some of the greatest factors aside from rainfall that play into the intensity of flooding events include river access to floodplains, the ability of the ground to absorb water, and the availability of vegetation for moisture uptake. Healthy forests and wetlands help mitigate flood damage; however, events leading up to a flood such as heavy rains that saturate soils, frozen ground that cannot absorb water, or snow melted by rain are also important factors in determining runoff volume.

Throughout Vermont's history floods of many different types brought great damage ranging from the regional to the local scale. Table 1 provides brief descriptions of a selection of the major floods from the past century. This summary of severe flooding from 1927 to the present day was compiled from the 1989 USGS National Water Summary Report for Vermont, FEMA's history of disaster declarations in Vermont, and the NOAA Severe Weather Database. The main floods that we focus on in our chapter are from 1927, 1938, 1973, 1976, 2008, and 2011 because of the widespread extent of the storm paths, significant damage, historical importance, and available data. The summary of storms in this table shows that many floods of a slightly lesser magnitude are a recurring and costly hazard in Vermont. This research also showed us that the majority of major flooding events were caused by the remnants of tropical storms that hit the northeast and rapidly delivered significant amounts of rain.

Table 1. Major Floods in Vermont History. All dollar values in this table are historical (not adjusted for inflation). Sources: NOAA Storm Events 2012, FEMA State Disaster Histories 2012, USGS 1989.

Date	Extent	Description
Nov. 3, 1927	Statewide	Most severe recorded in State's history. Recorded about 5-10 inches of rainfall. Deaths, 84; damage, $35 million.
Mar. 11-21, 1936	Statewide	Two floods: first due to rains and snowmelt, second due to intense rainfall. Damage, $1 million in Vermont, $100 million in New England.
Sept. 21, 1938	Connecticut River tributaries in southern area.	Hurricane crosses State. Stages in south higher than 1927 and 1936 floods. Deaths, 1 in Vermont; 700 in New England. Damage, $400 million in New England.
Jan. 1, 1949	Southern areas. Batten Kill	Snowmelt and as much as 10 inches of rainfall caused flooding in southern areas.
June 1, 1952	North-central areas.	Ten days of periodic rainfall in the Winooski River and Passumpsic River basins culminated in intense downpour. Some families evacuated from dwellings. Deaths, 4; damage, $500,000.
June 28-30, 1973	All areas except NW section.	Rainfall as much as 6 inches in 24 hours in some locations. State declared disaster area. Deaths, 3; damage, $64 million.
Aug. 9-10, 1976	Statewide	Hurricane Belle brought intense rains to much of State.
Apr. 18, 1982	Missisquoi and Lamoille Rivers.	Caused by snowmelt and moderate rains. Severe.
June 7, 1984	Winooski, Lamoille, and Wells Rivers.	Caused by severe thunderstorms. Central Vermont declared disaster area. Damage, $16.5 million.
July 6, 1984	Small stream near Williston	Severe thunderstorms; 6 inches of rainfall recorded. Train derailment caused by culvert washout resulted in 5 deaths.
Sept 1989		Severe storms and flooding FEMA disaster aid given
May 1, 1993	Lake Champlain	Flooding on the shore of Lake Champlain during the first half of May. Total damage estimates in Vermont for the entire flood episode were over $1 million dollars.
Aug 4, 1994	Northeastern Vermont	A cold front from Canada brought rain across northern Vermont this storm was joined by the remnants of Tropical Storm Dean enhanced the rainfall. It rained over 5 inches with over 10 reported at Mount Mansfield. Road closures and washouts occurred in Barre, Cambridge, East Montpelier, St. Johnsbury, Hardwick, Hyde Park, Johnson, Lyndon, Morristown, Underhill, Wolcott and Worcester. Extensive crop damage was also reported. President Clinton declared the region a Federal Disaster area.
Jun 12, 1996	Windham County	Torrential rains dumped approximately 6 inches of rain near Grafton. Flash flooding occurred and several roads were washed out.
Jun 15, 1997	Northern Vermont	A cold front stalled across Northern Vermont and focused heavy convective rain in this area the morning of July 15. Many roads were washed out.

Date	Extent	Description
Jun 18, 1998	Northern Vermont	Severe Storms and flooding Between 2.5 and 3.5 inches of rain fell with locally higher amounts in the mountains resulting in flash flooding of brooks, streams and small rivers. In the Vermont towns of Cambridge, Pleasant Valley and Hyde Park, numerous roads were washed out.
Sept 16, 1999	Southern Vermont	Tropical Storm Floyd brought high winds and heavy rainfall of 3 to 6 inches to Southern Vermont. The rain produced significant flooding across the region, which proved destructive. The combination of the wind and very saturated ground produced widespread downing of trees and power lines across much of Southern Vermont and as many as 2,000 people lost power. July 11, 2000 Flash Flooding in Addison, Bennington, Orange, Rutland, Windham, and Windsor counties due to two large consecutive storms.
Aug 3, 2003	Windham County	A slow moving storm produced 3 to 4 inches in about four hours time. The torrential rains took a toll, washing out roads in the city of Londonderry. Massive flooding occurred in the city of Grafton. This was the same area affected by the infamous Flood of '96 which was even more severe.
July 12, 2004	Essex and Lamoille Counties	Thunderstorms resulted in torrential downpours in Essex county, Vermont. Flooding occurred along Rte 102 between Canaan and Lemington. Several houses were flooded, especially in the Canaan area. Three cows were lost in the flood.
July 11, 2007	Eastern Side of the Greens	Localized heavy rainfall of 3 to 6 inches within a two hours resulted in flash flooding of several communities. A Presidential Federal Flood Disaster was declared in Washington, Windsor, Orange, Orleans and Caledonia counties. 3.6 million dollars in federal aid was paid out.
July 18, 2008	Northern Vermont	Governor James H. Douglas requested a major disaster declaration due to a tornado, severe thunderstorms, and heavy rains in Caledonia, Grand Isle, and Lamoille Counties.
Aug 6, 2008	Eastern and Northeastern	Severe flash flooding occurred in Addison county due to 3 to 5 inches of rainfall, with numerous road and bridge washouts. Additional flash flooding occurred along the headwater region and tributaries of the White River near Rochester as well as in Brandon and the North Eastern communities of Barnet, Danville and St. Johnsbury.
Oct 1, 2010	Central Vermont	Heavy rain, including moisture associated with the dissipated remnants of Tropical Storm Nicole, spread into Vermont and produced four to five inches of rain.Severe storms and flooding in Addison, Caledonia, Essex, Lamoille, Orange, Washington, and Windsor Counties. FEMA disaster declaration with 1.9 million dollars of public assistance.
Aug 28, 2011	Statewide	Tropical Storm Irene. See description below.

C. Tropical Storm Irene

On August 28th, 2011 Tropical Storm Irene hit Vermont. As the storm worked its way northward it unloaded a massive amount of precipitation over the mountains and valleys of the state. Much of Vermont experienced rainfall accumulations of over four inches, while many areas of the Green Mountains, especially on Eastern slopes, received over seven inches of rain (Vermont ANR 2012). Rivers spiked to record flows which tore through many of Vermont's towns, bridges, roads, and fields. Irene brought damage of a magnitude and extent only comparable to the Great Flood of 1927. Figure 1 shows a comparison of rainfall from the Great Flood of 1927 and Tropical Storm Irene.

Rainfall Accumulation in the Great Flood of 1927and Tropical Storm Irene

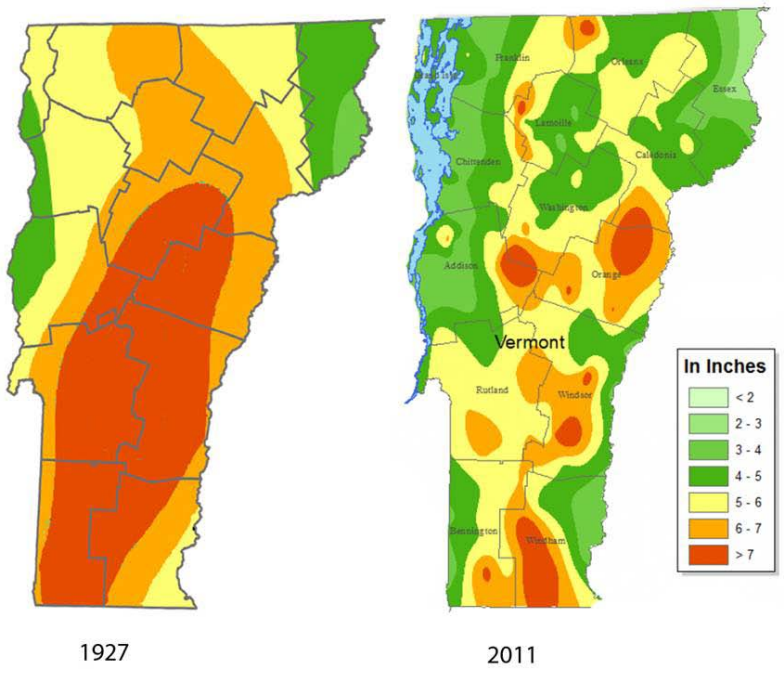


Figure 1. Rainfall Accumulation in the Great Flood of 1927 and Tropical Storm Irene. The map on the left of the 1927 flood was created by the National Weather Service based on historical reports of rainfall accumulation. The map on the right of Tropical Storm Irene was also created by the NWS. Even with the large difference in data quality it is interesting to see how the intense rainfall of both storms was located over the Green Mountains in central and southern Vermont (NOAA 2012).

Tropical Storm Irene brought extensive damage to Vermont's transportation networks. Over 500 miles of state roads and more than 200 state bridges were damaged. Estimates of the cost of this damage are between $175 million and $250 million. Vermont's town roads and

bridges also suffered greatly. There were over 2,000 road segments damaged, 280 bridges damaged and over 960 culverts washed out or damaged. Cost estimates for the damage to local roads also range from $175 million to $250 million. In addition, rail lines in the state sustained an estimated 21.5 million dollars of damage (Vermont ANR 2012). Damage to Vermont's roads and bridges is one of the greatest factors contributing to the great vulnerability of the state to extreme flooding events as even a small section of washed out road can affect a large number of people. Irene highlighted this vulnerability as the damage to state and local roads isolated thirteen towns, some of which had to receive emergency supplies via helicopter. Figure 2 shows post Irene road and bridge closures with the thirteen isolated towns highlighted in orange.

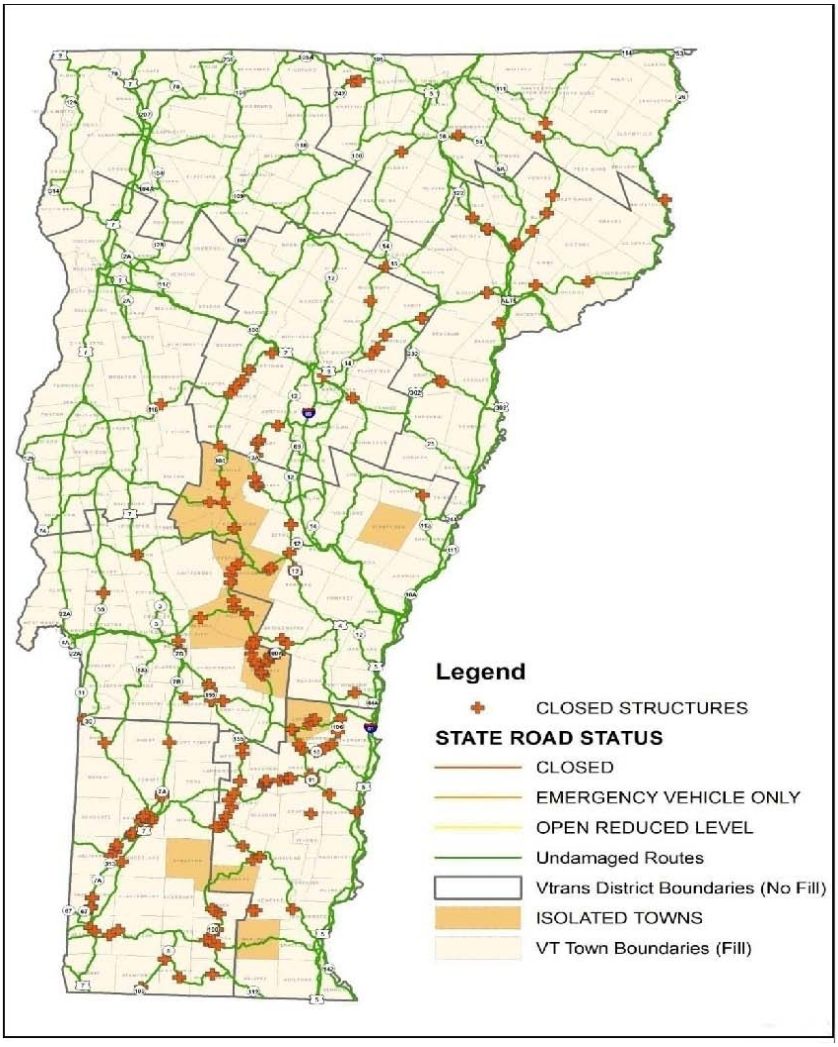


Figure 2. Damage to State Roads and Bridges showing communities cut off from transportation routes. Source: http://www.aot.state.vt.us/Irene/Irene.htm**.**

Figure 2 also shows that in the aftermath of the storm almost every single route that crosses the Green Mountains from St. Johnsbury to the Massachusetts border was damaged and closed. This bisection of the state was a great threat to emergency and relief efforts after the storm because of the difficulty to quickly access many communities. The Vermont Agency of Transportation (VTrans) and local road foremen worked hard to rapidly open routes to communities cut off by the storm. During this time Google worked with VTrans to provide a highly successful live mapping project of road closures ("VTrans' Irene Google Map" 2011). The ability to compile information from many different sources and individuals and visually display it in a user friendly interface that requires no GIS software was one of the great response success stories from Irene as it was an invaluable aid to the immediate response effort. The mapping project was also a useful tool that helped the fall tourist economy ("Vermont Rebuilding" 2011). We looked to this model of a synergy of government and community mapping as a successful method of post-disaster mapping and storing of information which will be detailed later in our chapter.

In the aftermath of the storm the greatest focus of state and local transportation officials and road crews was to access isolated areas and reopen major transportation routes. One of the great challenges in the wake of Irene was finding rock and gravel fill to reopen roads. As the River Management Group previously explained in Chapter 2 of this report, standard river management practices were temporarily suspended. The willingness of state officials to look the other way combined with the pressing needs of road crews and limited budgets of town road foremen meant that many rivers were essentially used as gravel pits during the recovery process ("Transportation bill clears" 2011). Mike Kline, a river scientist with the Vermont Agency of Natural Resources, explained a rough calculation that in the months following the storm 20% of the work in rivers reduced future vulnerability to floods while 40% maintained pre-flood vulnerability and 40% increased flood vulnerability (pers. comm. Kline 2012). One of the key lessons of transportation reconstruction following Irene is that while opening emergency access is paramount, the creation of temporary fixes can often go too far (Gram 2012). The massive amount of channelization, berming, and deepening of river channels had the opposite of the well-intentioned and desired effect of flood mitigation; instead it made the state much more vulnerable to flood damage.

D. Storm Discussion

During our study we found that each flood year provided a unique pattern of damage. While speaking about flood damage with several local road foremen, we noticed a wide variation in their accounts of damage from flood to flood; one flood might obliterate certain bridges or roads and the next might leave those same spots unharmed. While some areas of clear repeat damage emerged, other areas revealed somewhat haphazard patterns of damage. The two principle factors that contributed to discrepancies in damage were bridge age and associated construction method and variation in storm intensity, path, and origin. While there is information regarding when bridges were built and their construction type, it is often difficult to track down, and characterizing different storms on a local scale remains extremely difficult.

Due to the large spatial extent of a storm and the many types of flood damage, it was difficult to apply a consistent evaluation of damage for each storm and each flooding event. One of the best sources found for flooding damage costs over time on the state scale was the Extreme Weather Sourcebook published by the University Corporation for Atmospheric Research (UCAR). This study found that from 1995-2009 Vermont had 842 million dollars of flood damage or approximately 15.6 million dollars of damage per year, adjusted for inflation (UCAR 2009). This study ranks Vermont 42nd in the nation for flood damage; however, when we normalized the damage costs for population, the per capita flood damage was 25% higher than the flood prone state of Florida. This rough calculation shows that Vermont experiences much greater-than-average flood damage on the national scale.

For our project we wished to study the spatial extent of major historical storms and flooding events. This was so that we could best select and contextualize our case study areas as well as learn what areas in the state were most vulnerable to severe flooding. The USGS water summary report for Vermont provided some interesting visualizations and methodologies. Figure 3 shows their study of the areal extent of major floods from 1927 to 1973. The lighter tones represent the extent of flooding of the 25 year magnitude and darker tones represent flooding of a 50 year or greater magnitude.

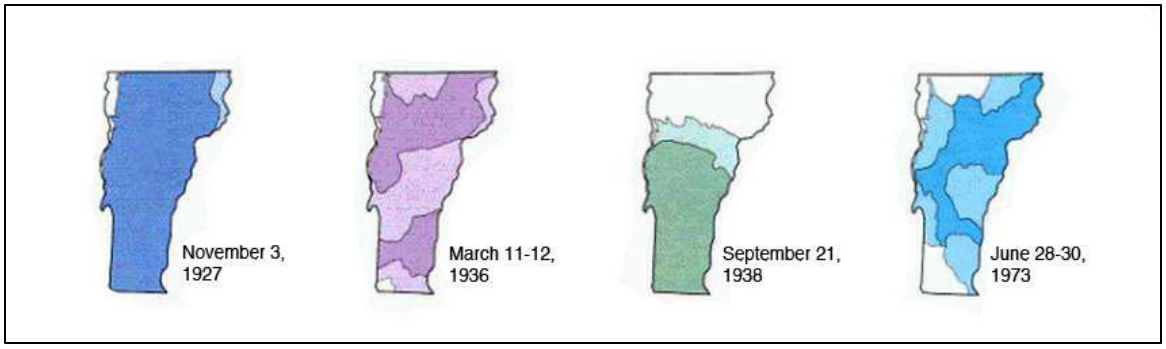


Figure 3. Areal extent of major floods 1927 to 1973. Source: http://md.water.usgs.gov/publications/wsp-2375/vt/index.html

The method used for this study took historical river level data from gauges on major rivers to see if they were at a greater than 25 year level or a greater than 50 year level. After this, the watersheds of the rivers and their tributaries were classified. Because flooding is often highly localized and because a river's flood stage does not always correlate to flood damage, as was the case of Otter Creek after Tropical Storm Irene, we created a more location specific analysis that focused on the aggregation of many flood years so that damage from smaller floods would not be lost in our analysis.

The most valuable source of information for this analysis was the storm events database from the National Oceanographic and Atmospheric Administration (NOAA). Since the mid 1990s NOAA has kept records of storm damage with approximate coordinates of storm damage and storm tracks as well as cost estimates of storm damage. A spatial analysis of these data from 1994 to 2011 shown in Figure 4 was performed so that storm paths and flood damage data could be analyzed.

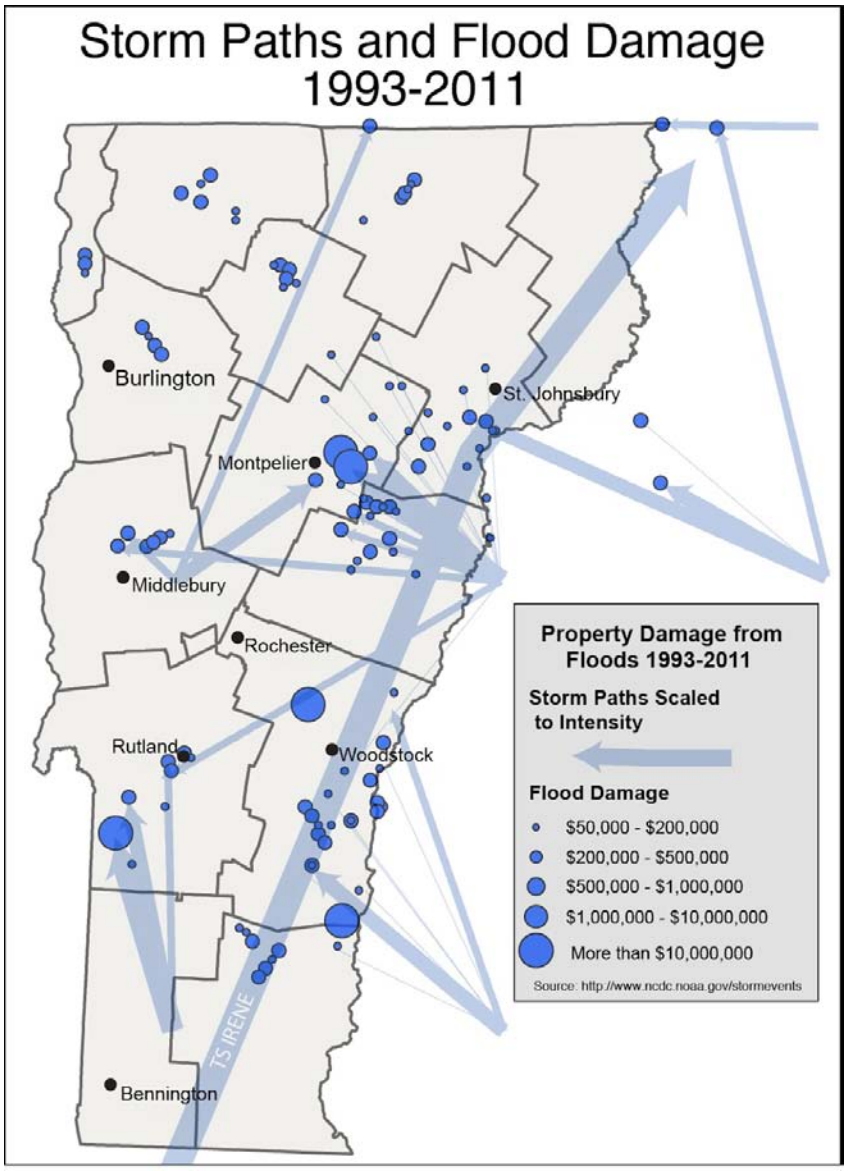


Figure 4. Storm Paths and Flood Damage 1993-2011. Source: http://www.ncdc.noaa. gov/stormevents/.

Storm events in Vermont that caused more than $50,000 of damage in the categories of flood, flash flood, lakeshore flood, and tropical storm were all displayed in ArcMap 10. For many flooding events specific latitude and longitude were provided; when this information was absent the centroid of the county was used for the location of damage. This data set also included start points and endpoints for storm and flood conditions. This information was also displayed with arrows to indicate trends of the origin of damaging storms in Vermont. The storm path arrows were scaled to the magnitude of damage of the event. Because the geographic data had a low level of precision the purpose of this analysis is to provide a visual overview of general

storm trends and locations of damage. The pattern of storm damage shows that the most damaging storms come from the south and southeast and that damage is focused on the eastern side of the Green Mountains.

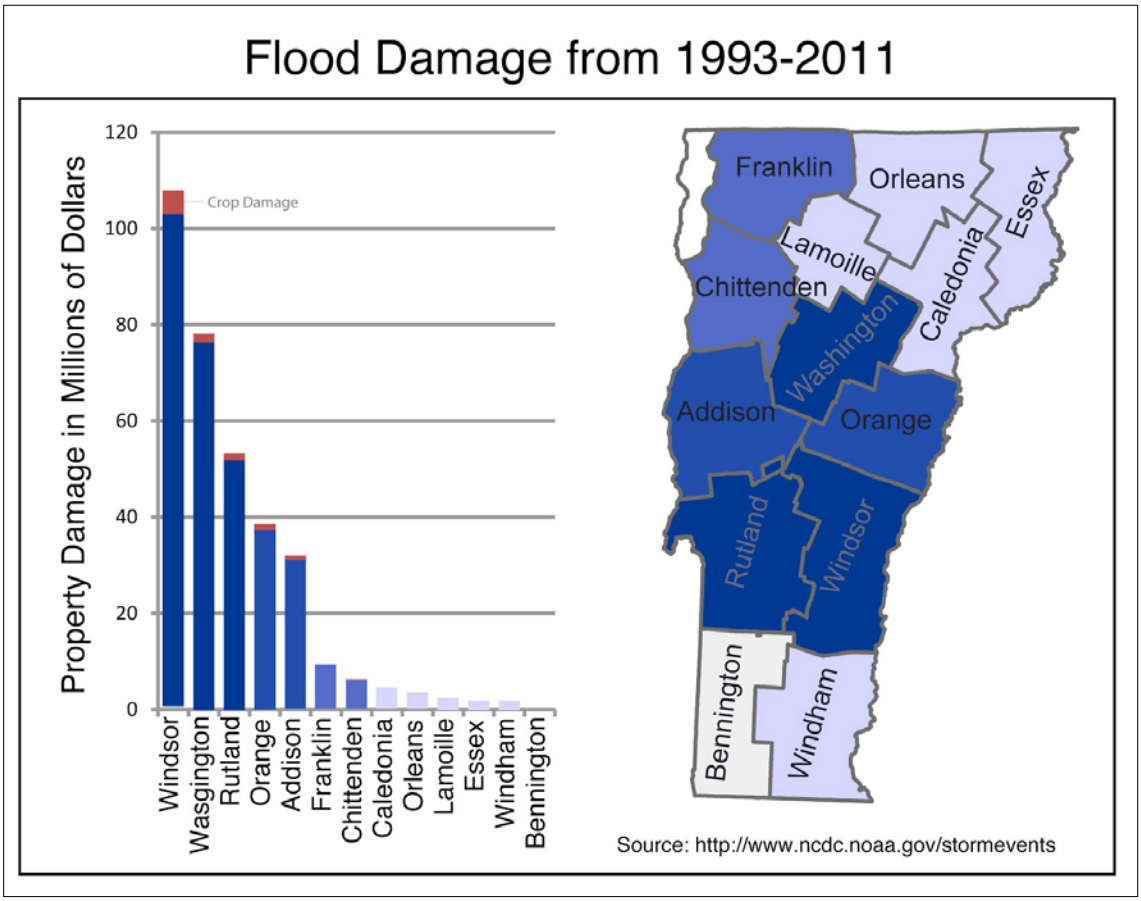


Figure 5. Flood damage to personal property from 1993-2011 for each county.

Figure 5, an aggregation of personal property damage per county from 1993-2011shows that Windsor, Rutland, and Washington Counties received the greatest flood damage. The concentration of damage in these counties is most likely due to the fact that many of their towns are situated along the spine of the Green Mountains. Counties in the north such as Chittenden sustained lower amounts of damage because they are less mountainous and because storm energy dissipates as weather fronts move in from the coast over the eastern slope of the Green Mountains. The northeastern parts of the state have probably sustained a lower cost of damage due to their smaller populations. This figure provides a good context for our case study towns of Hancock in Addison County and Plymouth and Rochester in Windsor County as these towns and those neighboring them have repeatedly received significant flood damage.

III. Case Study Location

A. Town Selection Process

The towns of Hancock, Rochester, and Plymouth were chosen as study sites on recommendations from Ethan Swift, Watershed Coordinator at the Vermont Agency of Natural Resources, and Todd Menees, River Management Engineer at the Rutland Regional Office, due to their susceptibility to repeat damage and the vulnerabilities highlighted during Tropical Storm Irene. Additionally, Hancock and Plymouth have fewer residents than Rochester, so comparisons between various aspects of flood mitigation, including state and national resource allotments, local efforts, and record keeping in the three towns proved to be informative.

These issues of funding and flood mitigation repeatedly emerge as important, particularly in rural communities. Rural infrastructure characterizes many Vermont towns, particularly those on the eastern slopes of the Green Mountains where flood damage recurs. Choosing to focus on towns with rural infrastructure and honing our focus on town-owned, rather than state-owned, roads makes our model of research and record keeping more applicable for towns throughout Vermont.

The Two-Rivers-Ottauquechee Regional Planning Commission (which encompasses Hancock, Rochester, and Plymouth) is currently finishing Phase I Stream Geomorphic Assessments (SGAs) with the follow-up Phase II SGA to be conducted in Fall 2012. Ethan Swift and Todd Menees both stated that a repeat damage assessment would be informative for the Regional Planning Commission's SGAs (and that this work would not be duplicative of any research currently being conducted). Kristen Underwood confirmed that historical research is a significant element of the SGA process. Further, town foremen are currently planning many town road, bridge, and culvert projects for the upcoming construction season, including over 40 in Plymouth alone. We were told that historic documentation of repeat damage could assist road foremen in making compelling arguments to town selectmen regarding proper sizing of replacement structures and the associated capital budgeting needs.

B. Town Information

Hancock

Hancock, one of the quin-towns, or five-town partners, on the east side of the Green Mountains is situated four miles north of Rochester along the White River. The town center is located at the junction of VT-100 and VT-125 (Figure 6). VT-100 runs along the White River through town and in much of the rest of the river valley. VT-125 leaves town heading west over the Green Mountains to Ripton.

As of the 2010 census, Hancock had 323 residents, with a median age of 48.3 years. Ninety-three percent of the population was white. There were 208 total housing units in Hancock, 150 of which were occupied, and 47 were designated as seasonal housing ("American FactFinder" 2010). Although the town had 67 residents under twenty years old at the time of the census, there is no longer a school in Hancock, and all school children must travel to the Rochester School each day. The school in Hancock, which had been one of the oldest schoolhouses in the country, closed in 2009 after 208 years (Rathke 2009).

Hancock was chartered in 1781 as an agricultural town and a common stagecoach stop. The Hancock Hotel, which was established in 1788, has stood continuously since then, serving as a stopping place for travelers, and a gathering place for the community. The town was largely wiped out by the flood of 1927, but eventually, industry returned to Hancock in the form of a large mill. This mill was the largest business in town since the 1970s, until it closed down within the past 10 years (pers. comm. K. Byrne 2012).

In the past forty years, five large floods—each causing significant road damage—affected Hancock. These floods occurred in 1973, 1976, 1998, 2008, and 2011. The Churchville Bridge, the largest town-maintained bridge in Hancock, has needed major repairs in all but the 1976 flood event.

Tropical Storm Irene damaged or destroyed approximately 10 bridges in the town of Hancock, leaving the town isolated from all directions. Arriving shortly after the closing of both the town's mill and school, Irene left many residents worried about the fate of their town, and whether they would be able to rebuild from this disaster.

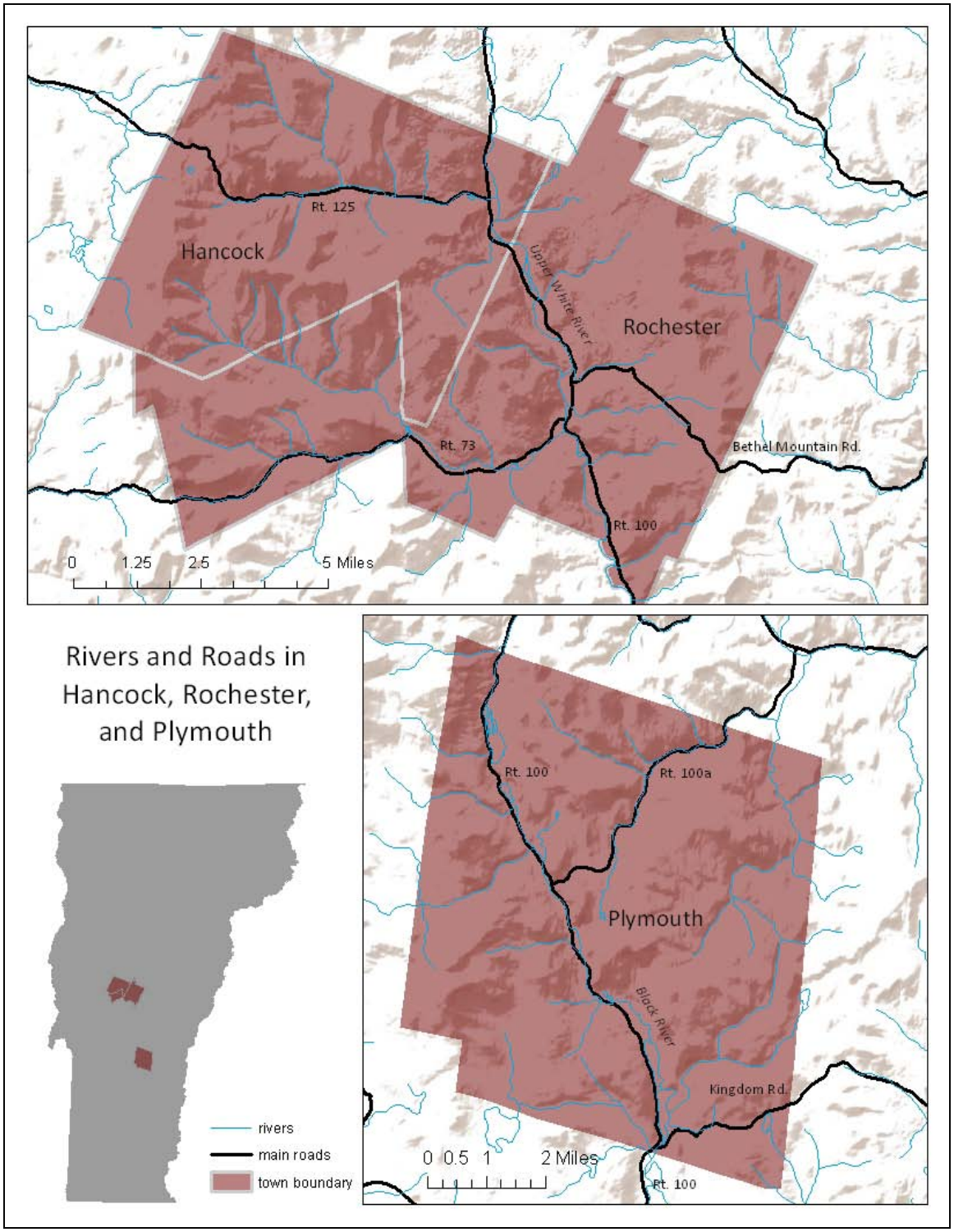


Figure 6. Rivers and main roads in Hancock, Rochester, and Plymouth.

Rochester

A center for community events and business, Rochester has the largest population center and land area of the five partner quin-towns along the White River Valley in central Vermont. The White River and VT-100 run side-by-side through Rochester (Figure 6). VT-73 connects Rochester to Brandon, VT and the west side of the Green Mountains.

As of the 2010 census, Rochester had a population of 1,139 in 532 households. The median age in Rochester is 50.1 years and the population is 96.7% white (American FactFinder 2010). The town has one schoolhouse, serving grades K-12 for Rochester, as well as the surrounding towns of Hancock, Granville, and Stockbridge.

Rochester was incorporated in 1781, and in its early years the economy centered on farming, mining, and the railroad. Agriculture is still a large part of the town's economy, but other businesses have grown in town, including a number of publishing companies. Many artists and writers reside in Rochester, and the town hosts a few galleries and festivals. The town is also well located for a number of outdoor activities, including biking, hiking, and skiing. Rochester has 232 seasonal housing units that are largely used by out-of-state residents looking to enjoy the Green Mountains.

The same large floods that affected Hancock in the past forty years -- in 1973, 1976, 1998, 2008, and 2011-- also affected Rochester, causing significant road damage. Damage from Tropical Storm Irene in Rochester was broadcasted through the press as some of the most dramatic in the state and included the excavation and dispersion of coffins from the Woodlawn Cemetery (Wilson 2011).

Plymouth

The town of Plymouth, incorporated in 1761, is located about thirty miles south of Rochester, also along VT-100 (Figure 6). Like Rochester and Hancock, it is located on the east side of the Green Mountains. The largest river in Plymouth is the Black River. The numerous tributaries to the Black River include Patch Brook, Money Brook, and other streams, which can rise quickly in flood events causing unimaginable damage. VT-100A is the only other state road in Plymouth and connects the town center northeast to Bridgewater Corners. Approximately 40% of land in Plymouth has public state conserved land status.

The 2010 census reported a total population for Plymouth of 619 with a median age of 50.8 years, and 98.2% of this population is white. Plymouth has 290 households, and an

additional 536 seasonal housing units (American FactFinder 2010). Hawk Mountain, a recently constructed private ridgetop development, has bolstered the economy with multi-million dollar homes; however, the influx of seasonal residents can contribute to divided priorities; FEMA assistance is tailored to serve permanent residents; seasonal residents cannot receive FEMA funding or buyouts (pers. comm. Larry Lynds 2012).

Over the past forty years, three large floods in 1973, 1976, and 2011 have caused significant damage in the town, with the most damage occurring in 2011. Unlike Hancock and Rochester, Plymouth was not damaged by flooding in either 1998 or 2008. In the seven months following Irene, Plymouth has been assigned five different FEMA officials, a situation that has impeded the processing of paperwork to pay off the 1.6 million Plymouth expended in flood repair. This 1.6 million is broken down into a $600,000 deficit that must be paid off by the fiscal year closing in June 2012, and a $1,000,000 loan.

IV. General Policy Discussion Post-Irene

A. Origins of Flood Policy

Federal flood policy in the United States originated from crisis events (Klein VT Law School Symposium 2012). Gilbert White, a former Geography professor at the University of Denver and known as the "father of federal floodplain management" (Klein VT Law School Symposium 2012), said, "[f]loods are acts of God, but flood losses are largely acts of man" (http://www.colorado.edu/hazards/gfw/bio.html). Flood preparation largely determines flood damage. In the early 1900s major flood response was focused on structures like levees, and practices evolved into significant engineering of floodways. The Great Flood of the Ohio River in 1937 led to the creation of flood disaster relief. As population increased near bodies of water across the country, unwise and risky floodplain development was common. Weather forecasting technology was sharpened in the mid-twentieth century, which contributed to an understanding of floods. Ultimately, the National Flood Insurance Program (NFIP) was established through the National Flood Insurance Act of 1968 after Hurricane Betsy (Klein VT Law School Symposium 2012). This program sets minimum standards for building in floodplains, and subsidizes repairs after disasters by providing money for people to rebuild to pre-existing conditions. Its effectiveness as a policy to prevent and mitigate flood damage is controversial in that the minimum standards are not sufficient for large flooding events and do not always serve the local

inhabitants well in all disasters. The NFIP encourages higher standards above the minimum, but more often than not, towns and states adhere to the baseline standards (Evans VT Law School Symposium 2012). The NFIP marked the beginning of large-scale federal disaster relief; today disaster relief encompasses a variety of federal agencies. Federal response to damaging floods has evolved over time, resulting in the layers of flood recovery policies that exist today (Klein VT Law School Symposium 2012).

B. Response to Irene

Federal response to Tropical Storm Irene in Vermont began officially on Monday, August 29th, after President Obama signed a disaster declaration for the state, triggering the use of federal funds to aid the recovery. The storm was declared a major disaster by FEMA on September 1, 2011 (FEMA 2012). At the federal level, the provider of most financial assistance, Irene recovery was spread across various federal agencies. The Vermont Congressional Delegation—Senators Patrick Leahy and Bernie Sanders and Representative Peter Welch—ensured that funding federal programs were a priority in Congress. Most notably, the Congressional Delegation avoided a $175 to $250 million shortfall by advocating for a waiver of the $100 million cap on emergency transportation funding and the 180-day time limit for repairs after natural disasters (Galloway 2011). Representative Welch introduced a bill to assist flooded farmers and helped create a bipartisan Irene recovery coalition in the House that included representatives from other states that were affected (Welch press release 2011). The coalition aimed to serve as a resource for affected states and also ensure that FEMA and other federal agencies were properly funded. The Vermont Congress ensured that the U.S. Economic Development Administration (EDA) received $200 million in funding for a grant program for which Vermont businesses, nonprofits, and municipalities can submit applications. This appropriation passed in the federal budget package in the fall of 2011, and the application process for these grants is ongoing until March 27, 2015 (Welch press release 2012). Additionally, $6,300,000 was designated for the USDA's Emergency Watershed Protection Program and $2,325,000 for the USDA's Emergency Conservation Program (Sanders press release 2012). The Emergency Watershed Protection Program focuses on homeowners in and near floodplains while the Emergency Conservation Program assists farmers in recovering their land. The Congressional Delegation also assisted the recovery effort by summarizing lists of

sources of federal funding and IRS tax credit information on their websites for individuals to access (www.disasterassistance.gov 2012).

After President Obama granted Governor Peter Shumlin's request for federal declaration of the disaster, the federal government issued aid. Federal money was largely sourced from the Federal Emergency Management Agency (FEMA), the Small Business Administration (SBA), the United States Department of Agriculture (USDA), the Department of Transportation (DOT), and U.S. Department of Housing and Urban Development (HUD). FEMA financial assistance was largely organized through Public Assistance (PA) under Section 406 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act and the Hazard Mitigation Grant Program (HMGP) under Section 404. These funds are generally given to the state and municipalities. Additionally, Individual Assistance (IA) was designated for private property. The HUD Community Development Block Grant Disaster Recovery (CDBG-DR) funds amounted to $21,660,211, and these funds were specifically designed to provide housing, business, and infrastructure needs caused by Tropical Storm Irene. HUD requires eighty percent of the state funds to go towards Washington and Windsor Counties (VTStrong.gov 2012). Despite these grants, the delay in reimbursement and cash flow after Irene has caused towns to take out loans to fund projects and wait for reimbursement from the state and federal government (pers. comm. Leno, Straus, Lynds 2012).

After Irene the DOT Administrator, Ray LaHood, made five million dollars in quick release emergency funds available to VTrans through the DOT Federal Highway Administration (FHWA) Emergency Relief Program for repairs to resume essential traffic flow. These funds were intended to fund the state road repairs. In total an estimated $125 million was designated by the DOT for Irene recovery in Vermont (DOT 2012). Beyond funding state roads through the FHWA, VTrans also funded grants to municipalities for town roads. The Town Highway Grants are organized through the VTrans Operations Division, who also administrates FEMA PA for town roads. The Town Highway Grants fund Class 2 road rehabilitation, town highway structures, and town highway emergency work. The "Orange Book", a VTrans handbook, provides specific detail and guidance regarding these grant programs for local officials (VTrans 2012).

C. State and Local Roads

State and local roads are funded by separate agencies. State road repairs were organized and funded by the Vermont Agency of Transportation (VTrans), which was aided by the DOT Federal Highway Administration (FHWA), while town roads were funded through FEMA PA or HMGP to the grantee (the State of Vermont) and then to the subgrantee (municipalities). Generally, for town road repair, municipalities took out loans following Irene and waited for reimbursement approval from FEMA and the state of Vermont. Both FEMA and state representatives certified costs and repair work, and due to the volume of damage in Vermont, there was a backlog of work, which in some instances meant a long delay in municipal reimbursements (pers. comm. Leno 2012). Towns were assigned a FEMA Project Specialist to mediate the reimbursement process. Communication and mutual understanding, therefore, was crucial to the administrative process. Challenges arose when a consensus on the scope of the project was not readily available or when there was significant turnover in FEMA representatives for a given town (pers. comm. Leno, Straus, Lynds, 2012).

D. Hazard Mitigation Grant Program

FEMA PA was the source of the majority of the funding supplemented by the HMGP, although the two grant sources were aimed at different types of work. As the name suggests, the HMGP is available for mitigation, or work that will prove more effective for future disasters over the long term. Applying for HMGP funding is more burdensome than PA funds because a cost/benefit analysis is required in addition to demonstration that there have been three historic losses. FEMA funds seventy five percent of the grant, and the remaining twenty five percent share is covered by a combination of the local and state governments. Funding provided to states under the HUD CDBG-DR program can be used for the non-federal share of FEMA cost shares (FEMA 2012). HMGP is designated as seven and a half percent of the estimated total disaster costs for a particular event. The funds are designed for structures and properties affected by the natural disaster, and the scope of work includes hazardous property allocation through buyout programs, relocation of structures to a safer place or elevation, or floodproofing. Additionally, up to seven percent of the HMGP funding can be used to establish state and local mitigation plans. In cases when there is enough PA funding, some elevation or floodproofing of structures can also be done through repairs completed with FEMA PA money, though this renders the structures ineligible for HMGP money (Ferguson Group 2008). There is no language stating that HMGP

cannot be used for intelligently re-engineering roads, but practically speaking, after Irene the majority of funds were not used to mitigate road damage. After Irene a large portion of the HMGP funds were used for property buyouts. For instance, there were three buyouts in Rochester, a case study town (pers. comm. Straus 2012).

E. FEMA Public Assistance

Public Assistance (PA) is available for a wide variety of repairs, but the reimbursement process can be daunting; FEMA's Public Assistance Policy Digest, which outlines the policy, is 155 pages in length (FEMA 2001). Projects are identified and initiated after the local FEMA kick-off meeting in declared disaster areas. Projects are generally divided into emergency and permanent work and subdivided by dollar amount into small and large projects (Figure 7).

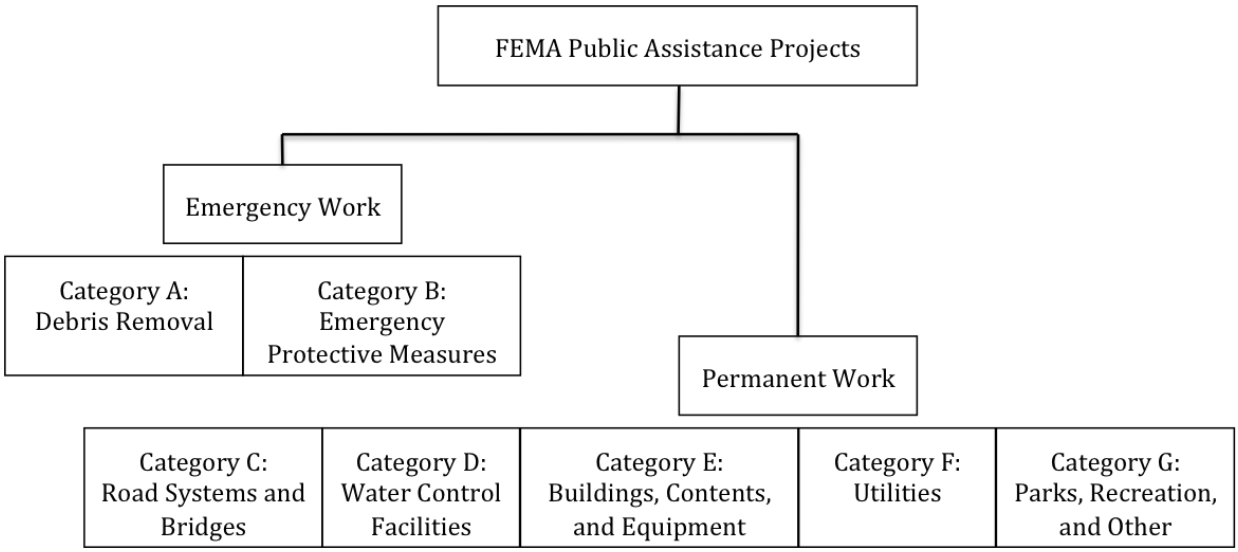


Figure 7. Categories of Public Assistance Projects.

There was some concern post-Irene that without the push for FEMA funding from the Vermont congressional delegation, FEMA would have been limited to funding only emergency work (pers. comm. Straus 2012). For fiscal year 2011, under which Irene fell, FEMA defined small projects as those, either emergency or permanent, between $1,000 and $63,900. Subgrantees are responsible for identifying projects and estimating costs of work, and FEMA reimburses as appropriate with the federal-state-local cost share. Large projects are approved on estimated costs based on FEMA's cost estimating format (CEF), but reimbursement is on actual costs. Because large projects are more expensive and typically more complicated to manage,

coordination between FEMA and the local authority is mandated throughout the scope of work and cost estimating discussions (FEMA 2012).

FEMA reimburses seventy five percent of the cost of repairing or replacing property that was damaged or destroyed in federally-declared disaster areas while the state and town would share the remaining twenty five percent (Minter 2012). Of the twenty five percent, the state pays either twelve-and-a-half or fifteen percent, depending on whether the town abided by particular repair standards set by the state (pers. comm. Leno and Straus 2012). In the event that a disaster is extraordinarily large, FEMA will reimburse ninety percent. Extraordinarily large, in specific policy terms means costs exceed one hundred and twenty seven dollars per person across the state. For Vermont, this means the cost obligation from FEMA would reach eighty million dollars (Gregg 2012). To date, FEMA has not declared the event large enough to merit the ninety percent cost share, but considering the projects still in the FEMA process, Vermont is nearly certain to reach this eighty million dollar threshold (pers. comm. Straus 2012). Having the FEMA share increased to ninety percent would mean that the state and town would each only be responsible for 5% of the costs. In February 2012, the state announced that its payments for repair of federally eligible infrastructure in the cost share would increase: per one-hundred-dollars-of-valuation town payments in the cost share are limited to no more than 103% of their property tax value (Minter 2012).

F. Funding Repeat Damage Mitigation

General Policies

Repeat damage to property and roads are addressed specifically through federal government funding. FEMA programs aimed at repeatedly damaged property include the Flood Mitigation Assistance Program, the Repetitive Flood Claims Program, and the Severe Repetitive Loss Program. These programs have specific requirements for funding and some implement a federal/non-federal cost share with the property owner; specifically, these programs require that the property be in a declared disaster area and that it be a part of the National Flood Insurance Program (NFIP) (FEMA 2012).

Alternative Projects

For town roads, there is an option under FEMA PA Section 406(c) of the Stafford Act to fund an alternative project when rebuilding the structure. Unfortunately alternative projects do

not receive as much funding as standard FEMA projects, which restore the structure to its pre-disaster condition. For a typical project valued at $100,000, FEMA pays seventy-five percent or $75,000. For an alternative project, FEMA pays ninety percent of the traditional seventy-five percent or $67,500 (FEMA 2012). This policy incentivizes towns to rebuild repeatedly damaged roads to pre-disaster conditions, rather than adapting and building more resilient roads.

V. Repeat Damage Assessment Data Acquisition Methodology

A. Personal Communication

Communicating with local officials and professionals was the first step in conducting our repeat damage assessment. These individuals provide access to flood damage documentation and critical first-hand knowledge of flood history. This local knowledge greatly expedited the search for more detailed data on the timing, location, and costs of flood damage. Our different personal contacts are outlined below.

i. Vermont Agency of Transportation (VTrans)

Our primary contact at the Vermont Agency of Transportation was Joe Segale, the Policy and Planning Manager. In the wake of Tropical Storm Irene, Segale works to integrate river management, climate adaptation principles, and land use/transportation planning to develop a resilient statewide transportation system. Repeat damage assessments are an integral part of the risk assessment process. Segale directed us to representatives within individual planning districts (Trevor Starr in District 3 for Hancock and Rochester, and Tom Roberts in District 4 for Plymouth). He provided information on damage to state roads, especially in the form of Detailed Damage Inspection Reports (DDIRs) (discussed below). Jonathan Croft of the VTrans Mapping Unit provided us with a historical map of road and bridge damage during the 1927 Flood.

ii. Vermont Agency of Natural Resources (ANR)

Our primary contact at the Vermont Agency of Natural Resources was Ethan Swift, a river scientist in the Monitoring, Assessment, and Planning Program of the Watershed Management Division of the Department of Environmental Conservation. Swift has detailed knowledge of the state's watersheds, major flood years within these watersheds, and areas which have repeatedly sustained major damage. He and his colleagues at the ANR, particularly Todd Menees, helped select our specific towns for case studies.

iii. Town Clerks

Town clerks in each of the three case-study towns (Cathy Curtis in Hancock, Joanne McDonnell in Rochester, and Barbara Rabtoy in Plymouth) provided us with access to town archives containing photographs and documentation of flood-related damages. They maintain close contact with FEMA officials assigned to their towns and have intimate knowledge of the costs and status of repair efforts and access to the associated paperwork. Through the town clerks and the FEMA contacts, we were able to obtain Project Worksheets (discussed below) for damage to town roads attributed to Tropical Storm Irene and other floods since 2008.

iv. Road Commissioners/Foremen

Finally, the road commissioners/foremen of each town (Jim Leno in Hancock, Larry Lynds in Plymouth, and Larry Straus in Rochester) shared their vast knowledge of local flood damage. In Plymouth, for instance, Larry Lynds was able to drive us to locations of Irene damage and identify the locations displayed in historical photographs of flood damage from 1973 and 1976. His knowledge allowed us to assign specific geographic coordinates to this historical damage, something that would have been impossible without his assistance.

B. Damage Reports

FEMA requires paperwork detailing damage and the scope of repair work to obtain public funds after federally declared disasters. These documents present a wealth of data on flood-related damage.

i. Project Worksheets (PWs)

Roads owned and maintained by towns and damaged during a federally declared disaster are eligible for FEMA Public Assistance (FEMA-PA) funds. To obtain FEMA-PA funds, local or FEMA officials must submit Project Worksheets (PWs). PWs are FEMA forms that document the scope of work and cost estimate for a disaster-related project. They are useful for obtaining data on damaged local infrastructure. PWs provide FEMA with the information necessary to approve repair plans and itemized costs prior to funding (http://www.fema.gov/government/grant/pa/faq.shtm#Q15). PWs are submitted to Public Assistance Coordinators and if approved are used as the basis for funding under the Public Assistance Program. Each project (usually an individual road, bridge, or building) must be

documented on a separate PW, but individual sites of damage can be combined under a single project.

FEMA has specific guidelines for the type and format of documentation included in Project Worksheets, much of which is useful for Repeat Damage Assessments:

- "Damage Location": In this section, PWs must describe the exact location of damaged sites. Whenever possible, this should come in the form of latitude/longitude coordinates. These coordinates especially aid the mapping process as they allow researchers to geolocate specific sites of damage.
- "Damage Description and Dimensions": In this section, "damage must be described in terms of the function of the facility, and its feature or items requiring repair." The result of these guidelines is a very specific report of the damage to each of a site's component parts (in the case of a road, one would not simply report that 'a section of roadway was washed out,' but instead separately describe damage to the guard rail, asphalt, gravel sub-base, and earthen embankment). This information is critical to a detailed Repeat Damage Assessment.
- "Scope of Work": In this section, "the scope of work necessary to repair the damage must be completely described and correspond directly to the cause of damage. The work should be specified in quantifiable (length, width, height, depth, capacity) and descriptive (brick, wood, asphalt, timber deck bridge) terms." This information is useful for establishing how particular segments of structures were repaired--it may be used to relate specific qualities of sites (i.e. what material a bridge was built with) to damage (or lack thereof) incurred at a later date.
- "Project Cost": In this section, all incurred and estimated repair costs (including the cost of materials, equipment, and labor) are listed and itemized. This information is useful for the cost-benefit-analysis part of a Repeat Damage Assessment.
- Photographs: Most PWs will also include photographs of the damaged sites they describe.

Unfortunately, FEMA only requires that Project Worksheets be kept by sub-grantees for three years from the date the State closes a grant. FEMA may need to be contacted directly to access older PWs, something our group attempted, but with which we achieved little success. A Freedom of Information Act request for all PWs related to flooding in the towns of Hancock,

Rochester, and Plymouth was submitted. While Irene-related PWs for Plymouth and Rochester were directly obtained in the offices of the Town Clerks, the Hancock office (which was flooded during 2008 and Irene) did not have these documents. They were obtained from Hancock's FEMA Project Specialist (Roland Luxenberg) via the Hancock Road Commissioner (James Leno).

ii. Detailed Damage Inspection Reports (DDIRs)

Any infrastructure that is part of the Federal-Aid Secondary Highway System (FAS) and damaged during a federally declared disaster is eligible to receive Federal Highway Administration Emergency Relief funds (FHWA-ER). To receive FHWA-ER funds, state officials must submit a Detailed Damage Inspection Report (DDIR) for each of its qualifying projects. In general, the FAS includes all state-owned roadways (which typically carry a route number) and town-owned major collector roads (those that pass through and connect several towns). DDIRs are therefore a good resource for damage to state-owned infrastructure. They are otherwise quite similar to Project Worksheets (see above). For our project we obtained all available DDIRs from Hancock, Rochester, and Plymouth from Joe Segale at VTrans. As with PWs, DDIRs are typically only held for three years after the project closes, and we were unable to obtain any DDIRs for flood events prior to Tropical Storm Irene.

C. Other Historical Documents

Since we were only able to obtain damage reports (DDIRs and PWs) for events since 2008, we used an assortment of historical records to find detailed information on past floods.

i. Annual Town Reports and Selectboard Minutes

Annual town reports and selectboard minutes typically contain budget information for repair work on town roads. These reports do not contain information on damage or repair work to state roads running through town, nor do they give the specific locations of damage along individual roads.

ii. Photograph Collections

The photograph collections kept in the town offices are by themselves interesting for documenting repeat damage, and along with knowledge from town employees, these photos can help to locate where the damage occurred along roads.

D. Policy Resources

In the realm of policy and funding, information was well-organized and summarized on the internet at http://vtstrong.vermont.gov/ and http://www.disasterassistance.gov/. Additionally, the individual websites for Vermont Congressmen proved beneficial in providing resources suited to individual townships and citizens. While these websites did summarize information, the complexity of the government scheme for disbursing funds was best understood through conversation with state officials, local road commissioners, and townspeople to gain an understanding of what policy avenues are practical and are being implemented. Viewing selectboard minutes and town reports helped provide some additional information. Newspaper and other media reports highlighted important policy options and decisions. Finally, the Vermont Law School hosted a symposium titled "After Irene: Law and Policy Lessons for the Future" on April 20, 2012. Hosted by the Vermont Journal of Environmental Law and The Vermont Law School Freshwater Working Groups, panels included topics ranging from disasters in the era of climate change, floods and land use, natural disaster policies, and creating a more resilient Vermont. Speakers included government officials, law professors, and non-profit leaders; this was an excellent resource, as there was a question and answer period in addition to each speaker's remarks (VT Law School 2012).

VI. Repeat Damage Assessment Findings

A. Compiled Damage Records

All damage records which we were able to assign a specific geographic location were compiled into a single master spreadsheet with fields for town, structure, location (latitude and longitude in a single cell, separated by a space), cost, and other notes. This spreadsheet was imported into Google Fusion Tables and visualized as a map. The resulting file of damaged sites is displayable within a simple internet browser with no additional proprietary software. Clicking the markers for a damaged site brings up additional notes and displays any associated photographs. Markers are color coded by year (1973- red, 1976- yellow, 2008- blue, 2011- pink). The most current version of this map can be found at the following link:

- Geolocated sites of damage in Hancock, Rochester, and Plymouth for all available years: https://www.google.com/fusiontables/embedviz?viz=MAP&q=select+col8+from+1M-QNgyfxk7-R922vALl5j0uKJQG_5K3-

dnoDQqQ+&h=false&lat=43.70626325658905&lng=-72.78326500000003&z=10&t=4&l=col8

Additional options to view the map are listed below:

- Only records of damage from 1973
  https://www.google.com/fusiontables/embedviz?viz=MAP&q=select+col8+from+1M-QNgyfxk7-R922vALl5j0uKJQG_5K3-dnoDQqQ+where+col2+%3D+'1973'&h=false&lat=43.58701602088677&lng=-72.78601158203128&z=10&t=4&l=col8

- Only records of damage from 1976
  https://www.google.com/fusiontables/embedviz?viz=MAP&q=select+col8+from+1M-QNgyfxk7-R922vALl5j0uKJQG_5K3-dnoDQqQ+where+col2+%3D+'1973'&h=false&lat=43.58701602088677&lng=-72.78601158203128&z=10&t=4&l=col

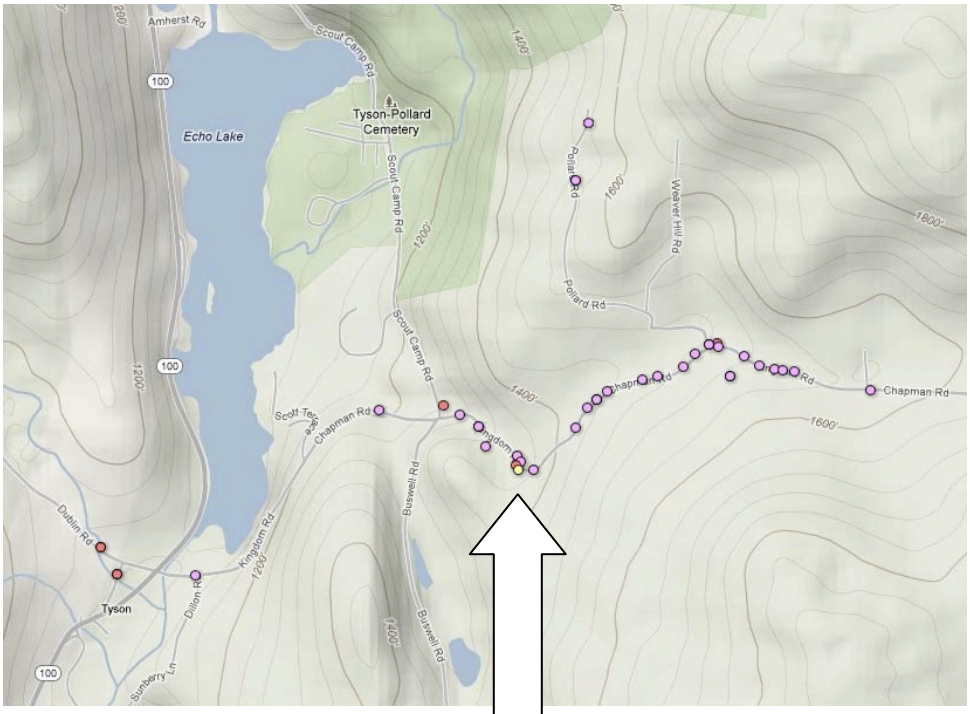
- Only records of damage from 2008 (Hancock and Rochester):
  https://www.google.com/fusiontables/embedviz?viz=MAP&q=select+col8+from+1M-QNgyfxk7-R922vALl5j0uKJQG_5K3-dnoDQqQ+where+col2+%3D+'2008'&h=false&lat=43.58701602088677&lng=-72.78601158203128&z=10&t=4&l=col8

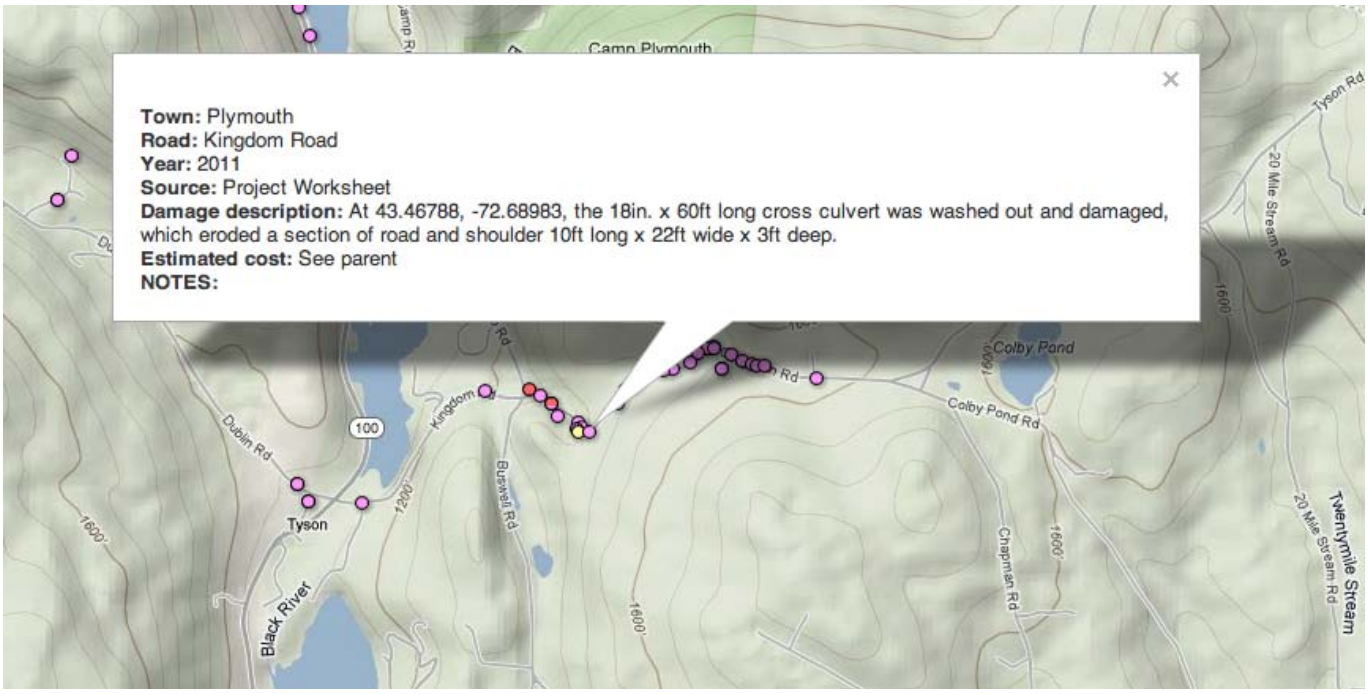
- Only records of damage from 2011
  https://www.google.com/fusiontables/embedviz?viz=MAP&q=select+col8+from+1M-QNgyfxk7-R922vALl5j0uKJQG_5K3-dnoDQqQ+where+col2+%3D+'2011'&h=false&lat=43.70626325658905&lng=-72.78326500000003&z=10&t=4&l=col8

B. Select Examples of Repeat Damage from Map

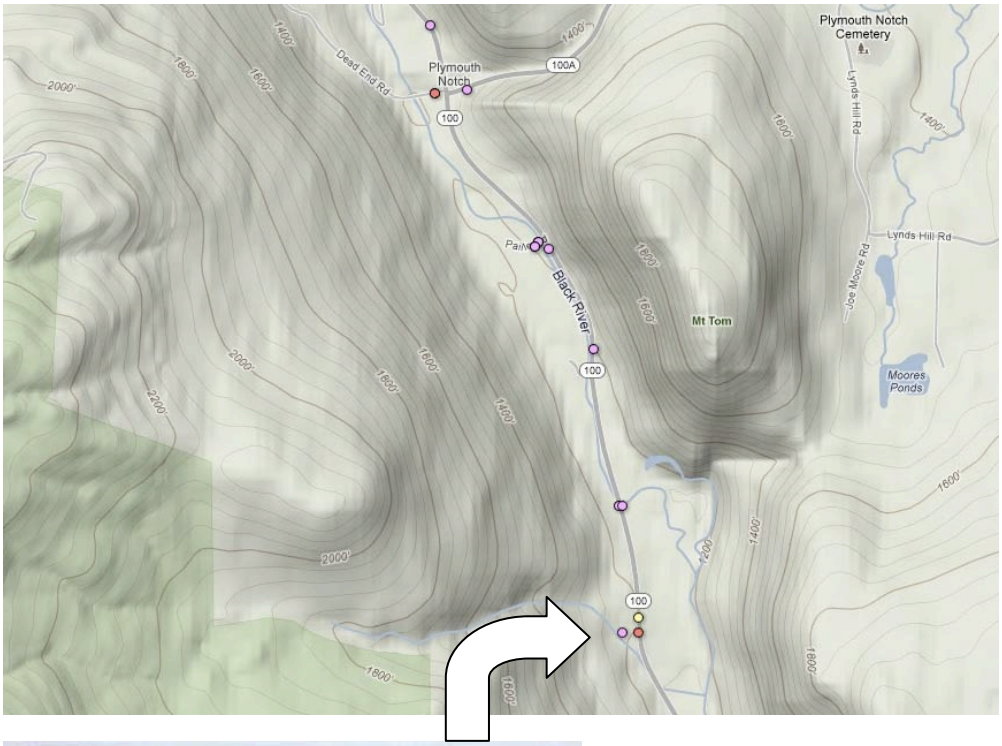
Plymouth, Vermont

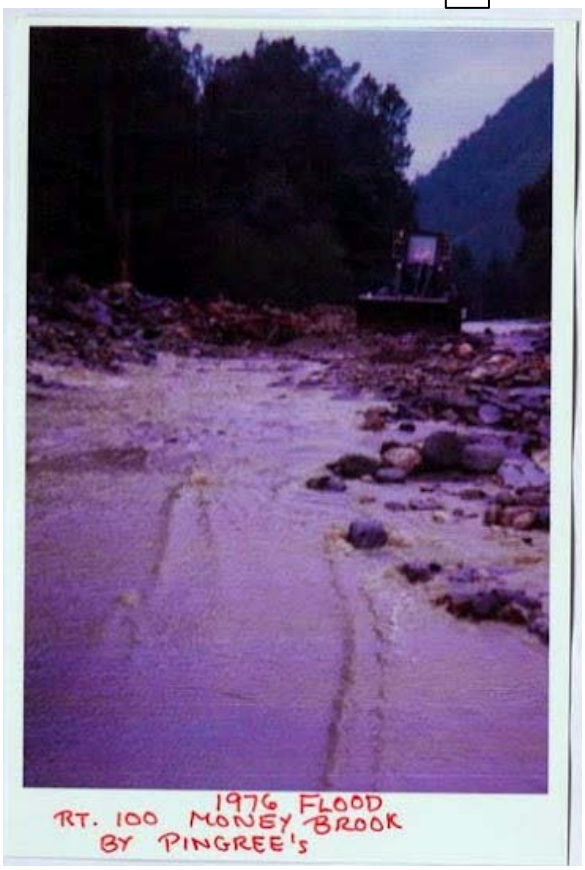
Kingdom Road:

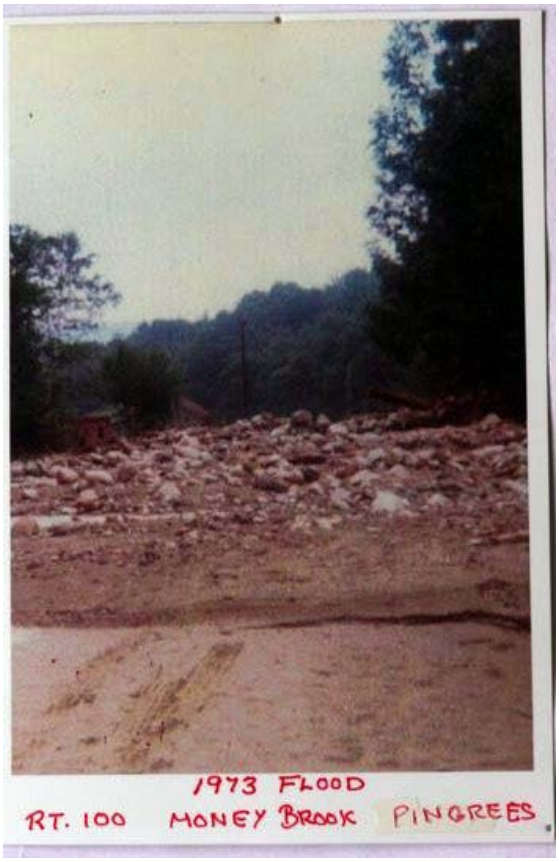



Town: Plymouth
Road: Kingdom Road
Year: 2011
Source: Project Worksheet
Damage description: At 43.46788, -72.68983, the 18in. x 60ft long cross culvert was washed out and damaged, which eroded a section of road and shoulder 10ft long x 22ft wide x 3ft deep.
Estimated cost: See parent
NOTES:
Camp Plymouth
Tyson Rd
20 Mile Stream Rd
Colby Pond
Colby Pond Rd
Kingdom
Dublin Rd
100
Tyson
Burnell Rd
Chapman Rd
Black River
Twentymile Stream
1600'
1200'

Rt. 100 at Money Brook:







Additional compiled data can be found in Appendix 1 and Appendix 2:

- **Appendix A**: Rochester town road damage costs: Compiled from Annual Town Reports (1938-1998) and from FEMA Project Worksheets (2008-2011)
- **Appendix B**: Plymouth town road damage: Compiled from historical photographs and the first-hand knowledge of Town Road Foreman (Larry Lynds)

C. Discussion of Maps/Geographic Distribution of Repeat Damage

Repeat damage assessments can be used to field-truth NFIP mandatory insurance zones, FEMA Flood Hazard Areas, and Fluvial Erosion Hazard zones. If repeat damage occurs in these zones then the zones are validated. As Fluvial Erosion Hazard zones are not yet available for our case study locations, Figure 8 uses data from PWs to assess FEMA Flood Hazard Areas. Though this analysis uses all available PWs to date, approximately half of the PWs are slated to be completed this summer. In this preliminary analysis approximately one-third of damaged bridges and roads lie within the Flood Hazard Areas. As road foremen continue to complete PWs during the upcoming season, this percentage will likely change.

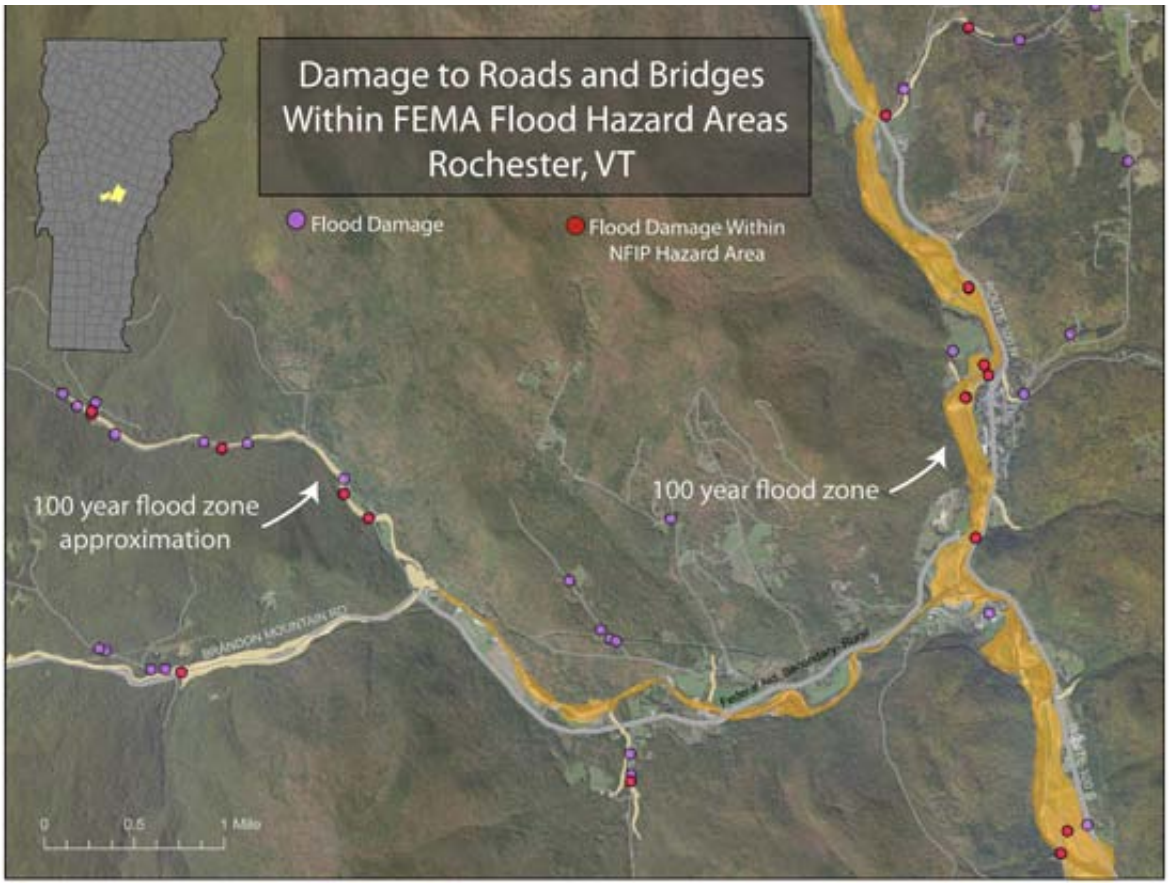


Figure 8. Damage to roads and bridges within FEMA Flood Hazard Areas, Rochester, VT.

D. Costs in Rochester and Plymouth

Compiling Costs

We aggregated all available historical records and PWs submitted to-date and calculated relative historical costs of road repair on town roads in Plymouth and Rochester. Due to the limited availability of records, we did not aggregate costs in Hancock. Given the relatively inconsistent record-keeping, relative historical costs are estimates. As road foremen continue to complete PWs during the upcoming season, more accurate relative current costs will surface.

Table of Costs by Road

Figure 9 indicates the historic and present costs to town roads in Rochester. Analysis indicates that four roads suffered repeat damage and the Pine Gap Rd. bridges alone cost the town over $300,000 apiece. Reconsidering the structure or location of these road segments could potentially benefit the town over the long term.

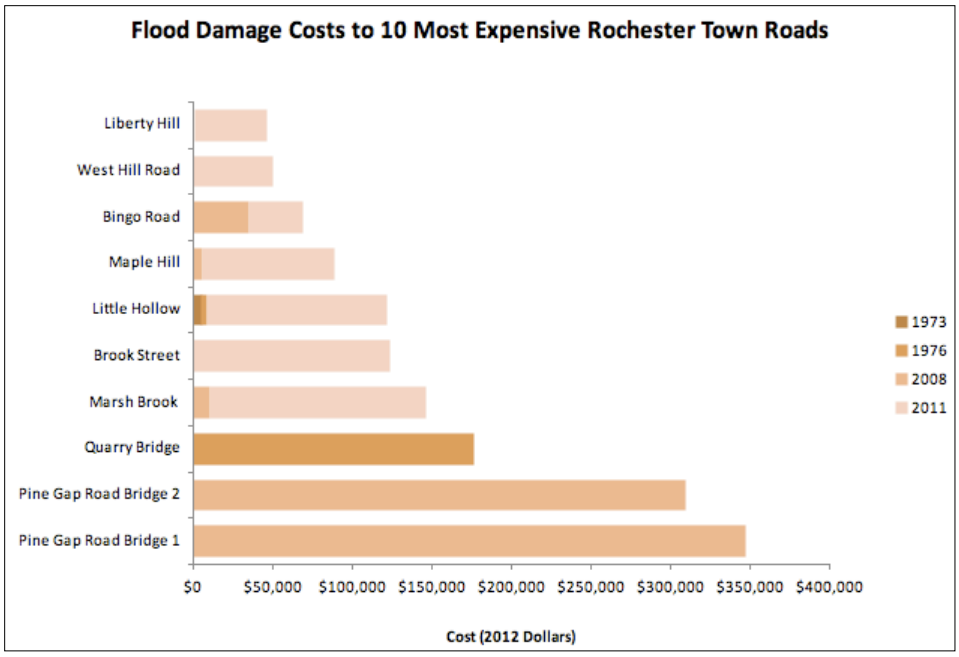


Figure 9. Historic flood damage costs to 10 most expensive Rochester town roads.

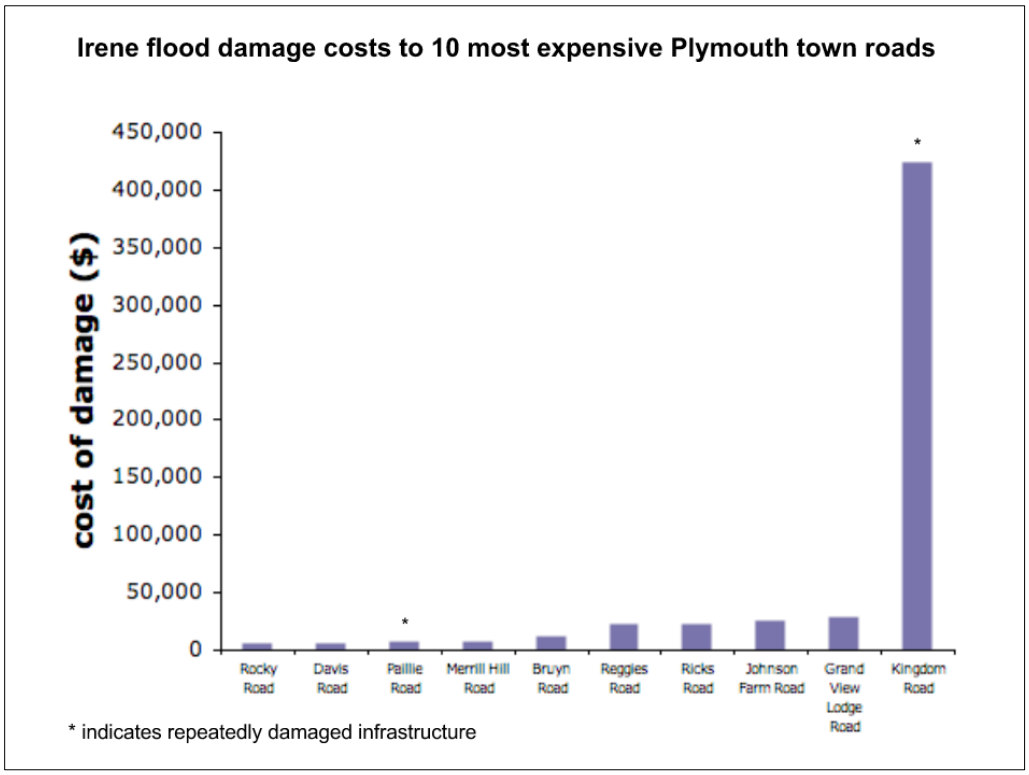


Figure 10. Irene flood damage costs to 10 most expensive Plymouth town roads.

Figure 10 portrays preliminary data on damages from Tropical Storm Irene for Plymouth. As evidenced by the graph, Kingdom Rd. costs the town substantially more in repairs than any other town roads, and has repeatedly suffered damage (see the preceding section of this report). Restructuring this road could potentially be lucrative in terms of savings. Though these figures are preliminary, continued assessment of this type can assist in prioritizing flood mitigation projects.

E. Types of Damage

Structures have changed significantly over the years, and the effects of new engineering and construction techniques are manifest in the damages incurred by flooding. Prior to the 1970s, steel or wood stringer and wood plank constructed bridges were easily washed away during flood events. As road engineering techniques evolved and new materials became more accessible, the integration of concrete in bridge construction led to changes in types of damage (pers. comm. Larry Lynds 2012). Though occasionally displaced, concrete abutments and decks help anchor the bridges; as a result of this, damages to road beds on either side of a bridge are more common than damages to the bridge itself (pers. comm. Larry Lynds 2012).

VII. Benefit-Cost Analysis

A. Outline of Benefit-Cost Analysis and Applicability to this Study

In order to receive FEMA funding for mitigation projects, a FEMA Benefit-Cost Analysis (BCA) must be administered, and must result in a Benefit-Cost ratio greater than 1.0. Benefit-cost analyses provide political leverage to prevent continued damage in historically damaged areas. For example, proof of repeat damage to houses on Great Roaring Brook in Plymouth will provide leverage for a housing buyout through FEMA (pers. comm. Larry Lynds 2012); however, some cost-benefit analyses present more complicated problems. Truly analyzing the costs and benefits of road improvement projects requires a very thorough analysis of many variables, including specific costs and benefits, qualitative impacts, monetization of all costs and benefits, sensitivity analysis, and future recommendations (Ganderton 2006). Many of these variables lie outside the scope of this study; without a thorough understanding of road engineering techniques, wetland and surface water conservation, forest conservation, and cultural variables in relocation, a benefit-cost analysis would be one-dimensional. Rather, this project

presents locations that have endured repeated damage, and suggests that those areas be further analyzed.

One limitation to a benefit-cost analysis involves estimation variables based on interrelated variables, such as the hedonic housing method that values environmental variables based on housing prices (Whitehead and Rose 2009). This method is fundamentally flawed; areas of low-income should not necessarily be low-priority conservation areas. Another, more specific limitation of benefit-cost analyses lies in changes in building code and engineering standards over the last 50 years. As noted above, structures have changed significantly since major floods in 1973 and 1976; the integration of concrete in bridge construction led to changes in the type of damage (pers. comm. Larry Lynds 2012). Historical benefit-cost analysis would require a nuanced understanding of variation in bridge construction over time.

B. Variables of Benefit-Cost Analysis

Though benefit-cost analyses are beyond the scope of our project, information on how to complete a benefit-cost analysis is included here to assist with further mitigation work in this area. There are four main types of data needed for a FEMA Benefit-Cost Analysis (BCA): 1) Detailed scope of work to be completed, 2) Estimated cost for construction project, 3) Estimated maintenance cost on completed project, and 4) Past damages and frequency of event (Gray and Sailer, 2010). The estimated costs both for construction and maintenance must be drawn up by engineers and fully documented in the report to FEMA (Benefit-Cost Analysis FEMA). Past damage information must also be fully documented, including USGS stream gage information, repair costs associated with each event, time of road closure, and the economic cost associated with the road being closed (Gray and Sailer 2010). The cost of road closure is based on the average number of trips per day taken on the road and the added time associated with the detour, which must all be surveyed and documented according to FEMA's standards.

C. Examples

Rt. 125 in Ripton, VT

After major floods in August 2008 washed out Rt. 125 in Ripton, Vermont, leaving it closed for nine days, the Addison County Regional Planning Commission (ACRPC) studied the road and river corridor and ran a FEMA Benefit-Cost Analysis (BCA) on a number of potential solutions to the repeated flood damage to this portion of Rt. 125 ("Middlebury River"). This

section of Rt. 125 is just over the crest of the Green Mountains, on the west side of the range, only 10 miles from the center of Hancock. The project was overseen by the ACRPC, with funding from VTrans, and implemented by Milone & MacBroom, Inc. and Landslide, Inc. This study provides an example or Benefit-Cost Analysis implemented recently on a road segment quite similar to many within our study region. For approximately a mile, Rt. 125 runs right along the south side of the Middlebury River, further constricting an already narrow valley. There are three sharp turns within this stretch that are repeatedly washed out, and major repair work has had to be done four times since 1995 (1996, 1998, 2000, and 2008). This study initially examined three alternative locations on which to re-route the road, and then completed a full BCA on two of these re-routing options as well as ways to mitigate flood damage while keeping the road in the same location.

After running the full BCA, the only option that was shown to be cost effective was the simplest of the four alternatives ("Middlebury River"). This option includes building floodwalls along the three sharp, vulnerable turns, as well as increasing the size of seven culverts and upgrading the ditch network along the side of the road. The floodwalls would replace riprap, making the edge of the road erosion resistant and creating more space for the river. The estimated cost for this option is $1,600,000, resulting in a Benefit-Cost ratio of 1.15, and this option would therefore be eligible for FEMA funding. The option of moving Rt. 125 higher up the ridge to the location of a historic road known as the Center Turnpike has an estimated cost of $6,560,000, which includes the cost of the new road base and surface, along with seven new culverts and one new bridge. This option would give the Middlebury River full floodplain access and allow tributaries to flow freely into the river; however, this option has a BC ratio of 0.29, making it ineligible for FEMA funding.

Better Backroads

The Better Backroads program, sponsored by VTrans and the Vermont Agency of Natural Resources (ANR) and administered by the Northern Vermont Resource Conservation and Development Council is another program that aims to improve eroding structures and create a mutually sustainable relationship between roads and the nearby rivers and streams. The Better Backroads Program provides up to ten thousand dollars to improve road erosion issues. In addition to offering grants to towns to fix road erosion problems, the Better Backroads Program offers grants to towns to inventory and develop capital budgets to fix road erosion problems,

provides on-site technical assistance to towns, and publishes the Vermont Better Backroads Manual which details cost-effective procedures towns can use to reduce the impact of their roads on streams, lakes and wetlands (VTwaterquality.org 2012).

Across the state of Vermont, over fifty-five percent of the local town roads are unpaved or gravel, so it makes sense to focus on this type of road surface (NVTRCD 2009). The grants demonstrate the use of cost-benefit analysis and are divided into two categories, Road Inventory and Capital Budget Planning and Correction of a Road Related Erosion Problem (VTwaterquality.org). According to the 2009 manual, the program is aimed to inform local decision makers to ensure decisions related to erosion and sediment control are cost-effective. Value, as defined in the manual, often means wise investment of the limited local revenues in a productive way to work towards longer-term sustainability (NVTRCD 2009). The 2009 manual outlines specific best practices for Better Backroads projects: crown roads to allow water to move quickly from the surface into the ditches (approximately one half to three quarters inch per linear foot); stabilize all exposed soil with seed and mulch; install erosion control blankets or hydroseeding as soon as possible; line ditches with slopes greater than or equal to five percent with stone; line ditches with slopes less than five percent with vegetation (seed and mulch); direct runoff into vegetated areas; where possible, avoid concentrating runoff and keep runoff velocities as low as possible; install culverts with a minimum diameter of 18 inches; install stone aprons at culvert outlets where erosion is occurring; install headers and/or wingwalls on culverts where erosion is occurring; schedule and perform regular inspection and maintenance on culverts and ditches; stabilize eroding banks with vegetation or stone; disturb in a day only an area that can be stabilized that same day; and finally, after September 15th, stabilize soils by hydroseeding or covering with erosion control blankets, not just seed and mulch (NVTRCD 2009).

These techniques have demonstrated to be cost saving in the long term, as demonstrated by estimates of properly versus improperly constructed ditches from Everett Hammond, the Director of Public Works in Rockingham, Vermont. His cost comparison reveals that, over a twenty year period, a properly constructed ditch costs $26,000 per mile, while an improperly constructed ditch costs $36,000 per mile. This indicates that there is an extra $10,000 per mile cost over twenty years if ditches are designed improperly (NVTRCD 2009). The FY 2012 expenditures for the Better Backroads program total $415,738.29 as of mid-April 2012, although there were no grants allocated for Hancock, Plymouth, or Rochester. It is estimated that the total

costs allocated through the program will surpass the $441,488.28 spent in FY 2011 (pers. comm. Becker 2012).

Wetland Restoration for Flood Mitigation

Because of their water storage potential, wetlands are thought to reduce peak flood flows and aid flood attenuation. Since wetland drainage reduces this ecosystem service, multiple studies have explored the potential for wetland restoration to reduce flood damage. That said, only one study has performed an extensive benefit-cost analysis on the feasibility of restoring previously drained wetlands to reduce flood damage (Shultz and Leitch 2003). Ultimately, the study (conducted in North Dakota's Maple River Watershed) yielded benefit-cost ratios for various restoration options between 0.2 and 0.7 and thus did not recommend public funds be spent on wetland restoration in the study region as a means to mitigate flood damage.

VIII. Post-Irene Policy Analysis and Recommendations

A. Streamline the Hazard Mitigation Grant Program (HMGP)

Specific improvement areas in the policy sector were identified both from personal communication with officials and analysis of the policy process post-Irene. For example, the FEMA reimbursement process funds structures to be rebuilt to pre-disaster conditions. FEMA consistently rebuilt in the same location and provided less funding for projects focused on repositioning roads, building larger culverts, or other strategies that would increase the resilience of the infrastructure. Alternative projects were not widely discussed in our case study towns because it was generally desirable to have more funds to repair or recover pre-existing structures.

The Churchville Road in Hancock provides a case study for this trend. Located east of Rt. 100, Churchville Road provides direct access to eleven households located around Howe Brook. A road on the other side of the mountain into Rochester provides an alternative route for this community. Road Commissioner James Leno organized a vote from the town selectboard after describing the cost share differences between a traditional PA and the alternative project program. If the town had elected to engage in the alternative project program, the town would not have rebuilt the road, but instead used the money elsewhere, and residents would have continued to access their homes through Rochester, according to Commissioner Leno. Ultimately, the selectboard voted to receive the funds to rebuild the road to its pre-existing condition (pers. comm. James Leno 2012).

FEMA contends that it is not cost-effective to dramatically upgrade infrastructure nor is it "cost effective to rebuild in a manner that virtually guarantees future loss, and FEMA needs to be more consistent in applying its new mitigation policy" ("Options for State Flood" 1999). Given the established framework and funding mechanisms FEMA generally relies upon (PA, HMGP, etc.), this suggests that more than the standard 7.5% of funds should be allocated for the HMGP and the application process for HMGP should be streamlined and accessible in situations without record of three historical losses or easy access to cost/benefit metrics. Streamlining the HMGP provides a method for funding repeat damage mitigation that does not dramatically change the precedent, yet would benefit the people in areas that are at risk for repeat damage.

B. Thinking Beyond the National Flood Insurance Program (NFIP)

The National Flood Insurance Program (NFIP) is mandated for properties in FEMA designated flood plains. Properties are insured through private companies which collect a portion of the premiums and send a portion to FEMA (FEMA 2012). NFIP is another flood policy that was criticized by officials and scholars in the wake of Irene for lack of understanding of resiliency planning. Specifically, a common critique is that federal insurance undervalues natural conservation in disasters because people can be paid to rebuild in a floodplain. After Irene, NFIP flood insurance claims paid out 49.2 million dollars, while from 1972-2010 the amount paid out in Vermont was 7.9 million (Evans VT Law School Symposium 2012). By paying people to rebuild in floodplains, the NFIP has enabled risky development.

The limits that exist in the NFIP Flood Insurance Rate Map (FIRM) are not typically understood by insurance plan holders. These prediction maps are essentially risk maps because there is really no way to accurately predict flooding (Evans VT Law School Symposium 2012). An economic critique of the NFIP argues that the high upfront costs in purchasing a home overshadow the relatively lower increased costs of insurance in a floodplain that can easily be ignored or absorbed. Therefore, raising property values and upfront costs in floodplains could discourage people from buying and building in flood-prone areas. Implementing this upfront cost would be difficult politically and would take a significant amount of political capital, but could discourage risky floodplain development (Pidot VT Law School Symposium 2012). The NFIP cannot be relied upon alone to protect from damage in floodplains and discourage risky development; a more integrated and dynamic program that uses well researched maps as risk projections rather than flood predictions could aggressively disincentivize floodplain

development while still protecting existing structures and property. The NFIP can be a stepping stone to this goal, but it cannot be relied upon alone for flood protection.

C. Record Keeping

One of the biggest obstacles in our study of historical repeat damage in Vermont was the lack of records, which has the potential to inhibit towns when applying for mitigation projects which require thorough documentation of costs associated with each event of repeat damage. In recent years, Project Worksheets (PWs) and Detailed Damage Inspection Reports (DDIRs) have been filled out for all work associated with flood damage to town and state roads, respectively; however, these records are generally not kept by the towns or the state after three years. Minimal information on flood costs, largely without details of the location of the damage, is included in town reports, but this is not enough information with which to administer a Benefit-Cost Analysis. We recommend towns begin to archive these PWs and DDIRs in order to have a complete record of the locations and costs of flood damage. Of the three towns we studied, Rochester has the most detailed records available, and from these records we were able to compile a table organizing the flood damage costs to town roads by road and by event (See Appendix A). This table is a straightforward, simple way to see which roads are most vulnerable to flooding and the costs associated with these flood events, but there are still significant holes. The total cost for the 1998 flood is known, and there is a list of all roads that were damaged but there is no budget line for how much was spent on repairs for each road. Over the course of the last century, many road names changed, making some comparisons more difficult. In addition, not all PWs for Tropical Storm Irene have been completed, and so the cost given for 2011 is not the total.

It may also be useful for Hancock, Rochester, and Plymouth to continue to add to the map database we have set up for this project after future flood events. With this database the towns would be able to identify the locations best suited to mitigation projects by looking spatially at instances of flood damage from separate flood events. This database would also lead towns to the relevant PWs and DDIRs for a specific road or project.

D. FEMAs Inundation Model and Fluvial Erosion Hazard (FEH) Zones

Across the nation, flood insurance rates and flood mitigation planning are based on elevation models, addressing inundation flooding rather than fluvial erosion that is more common in mountainous terrain. "Over 75% of damages in Vermont caused by the five major floods of the 1990s were due to fluvial erosion. FEMA's regulations recognize that the NFIP standards offer minimal protection against inundation and erosion hazards, and they explicitly encourage communities to adopt more protective standards" ("Fluvial Erosion" 2012). The Watershed Management Program within the Vermont Agency of Natural Resources (ANR) encourages communities within the state to adopt Fluvial Erosion Hazard (FEH) zones into the planning and zoning of their land. In order to establish FEH zones, stream geomorphic assessments must be done for the reach of the river. As of December 2011, 17 Vermont towns had adopted FEH zones (pers. comm. Swift 2012). Many other towns are in the process of collecting geomorphic data to enable them to establish FEH zones and we encourage this process.

IX. Conclusions and Implications

A. Policy Outlook for the Future

Because each disaster is unique and the people affected are not homogeneous, it is important not only to assess the policies used after Irene but to also persist in seeking new alternatives and sources of funding for the future. Disasters occur with little notice and are quick in causing damage; government, however, is capable of responding quickly, but also can be slow to respond with solutions that fit long term goals. For instance, river engineers after Irene were forced to rush what would be days of research into a ten-minute conversation, demonstrating that both the crisis period following disaster and the longer-term retrospective period are important (Kline VT Law School Symposium 2012). The recovery period, therefore, must be viewed in the long term to understand it completely. The policies surrounding Irene are continuously evolving, even currently in the Vermont legislature and at federal agencies. For example, the Congressional Delegation announced on January 18, 2012, nearly five months after the storm, that $8.7 million dollars would be available from the USDA for farmers and property owners (Sanders press release 2012). On January 20, 2012, Governor Shumlin announced that HUD would allocate CDBG-DR grants adding up to $21,660,211 to communities in response to Irene.

Some of these funds would help cover the twenty-five percent local share in HMGP grants. Because of the long application process between the state and HUD, the community applications will become available in June or July 2012 (VTStrong.gov 2012). Additionally, on April 18, 2012 the *Burlington Free Press* announced that the National Guard would be reimbursed four million dollars by the Federal Highway Administration (FHWA) for their emergency work. This was the result of a policy dispute where Vermont Assistant Attorney General Daniel Dutcher sent a memo to the FHWA saying that not reimbursing the National Guard was bad policy in that it may make other states reluctant to deploy National Guard troops in times of emergency. The change in federal policy allows for reimbursement from the FHWA in certain situations that Vermont qualified for after Irene (Gram 2012). Clearly, federal agencies are still allocating funds related to Irene recovery, and patience with the federal government funding mechanisms is crucial. In addition to several other agencies, FEMA is likely to be working with Irene recovery projects well into the future. Therefore, constant evaluation of policy and attention to all potential sources of funding are important in disaster recovery for an extended period of time, far beyond the initial recovery period.

Vermont is in a unique position, with a total population smaller than many municipalities in the country, to reconsider its management of flood response. This means that a relationship between the state government down to regional planning commissions, counties, and towns should be dynamic, evolving to the citizens' needs. Work done by the Psychology of Flooding Group (presented in Chapter 4) addresses some of these issues; citizens should be informed of flood hazard zones and their own efficacy to address the potential effects of flooding. Without a doubt, there needs to be a cultural competence to tackle problems from a multi-faceted, interdisciplinary approach, utilizing the knowledge of authorities across state agencies and local and regional levels of government. Regional planning commissions are useful middle men in the crucial relationship between the state and towns. Finally, the government does not need to be an institution that people distrust. Instead, as a society, we should invest in government while ensuring accountability both for the institutions of government and the political leaders that represent our citizens (Mears VT Law School Symposium 2012).

B. The Value of Repeat Damage Assessment in Relation to Climate Change

Flooding is already the most frequent, damaging, and costly natural hazard experienced in Vermont (Kline and Dolan 2010). Climate change models show that this hazard will continue

to grow. As Vermont becomes a wetter state, it is likely to experience a higher frequency of large floods. It was previously thought that storm the size of Irene was the hundred-year storm, or that that each year there was a 1% chance of a storm of this magnitude. Recent studies have found the probability of storms like Irene striking the Northeast is more realistically in the range of 5% to 30% each year—Irene could be the new twenty-year or three-year storm (Ning et al. 2012).

Documenting the location of repeat damage in a clear manner that can be easily accessed by citizens and officials is a crucial first step in mitigating repeat damage. This information will aid in the planning and decision making process of road relocation, road repurposing, and the development of new construction techniques. Though high in social capital, towns like Plymouth, Hancock, and Rochester cannot afford to rebuild roads every three, or twenty, years, even with federal aid. During Irene alone, washouts on Kingdom Rd. in Plymouth caused over $420,000 in damages. Kingdom Rd. has experienced severe washouts three times in the last 30 years. With more complete records, effective cost analysis can be performed to assess the value of alternative projects. Ease of accessibility is key for future record keeping so that decisions from the scale of local selectboards to the state can be informed by a spatial and temporal understanding of flood damage.

With increased storm events, relocation or re-engineering of Kingdom Rd. and the many other Vermont roads built in stream beds and fluvial erosion hazard zones will have long term benefits. By conducting repeat damage assessment, town planners can use the political leverage of repeat damage to argue for more resilient planning in the face of climate change. Transportation planners need to use these repeat damage assessments to develop strategies for more resilient planning and construction methods.

X. Bibliography

"After Irene: Law and Policy Lessons for the Future." Vermont Law School Symposium. 20 April 2012.

"American FactFinder." U.S. Census Bureau. 2010. Web. April 2012 http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk.

Becker, Jarrod H. Personal Interview. 19 Apr. 2012. Business Manager, Northern Vermont Resource Conservation & Development Council (Better Backroads Program).

"Benefit-Cost Analysis." U.S. Federal Emergency Management Association. U.S. Department of Homeland Security. Web. 1. Mar. 2012. http://www.fema.gov/government/grant/bca.shtm

"Bernie Sanders, U.S. Senator for Vermont." United States Senate. Web. 1 Mar. 2012.

"Bridge Damage in VT: Comparing the flood of 1927 with TS Irene." Geosprocket. Web. 1 Mar 2012.

Clifford, Deborah Pickman, and Nicholas Rowland Clifford. "The Troubled Roar of Waters": Vermont in Flood and Recovery, 1927-1931. Durham, N.H.: University of New Hampshire Press, 2007.

Disaster Unemployment Assistance. U.S. Department of Labor. Web. 1 Mar. 2012. http://workforcesecurity.doleta.gov/unemploy/disaster.asp.

Douglous, Jim. ENVS 401 Lecture. Middlebury College: Middlebury, Vermont. 8 March 2012.

Engel, Kirsten. "State and Local Climate Change Initiatives: What is motivating State and Local Governments to Address a Global Problem and What Does this Say about Federalism and Environmental Law?" Urban Lawyer, Vol. 38, p. 1015, 2006. Web. http://www.law.arizona.edu/faculty/facultypubs/documents/engel/als0636.pdf.

FEMA. "FEMA: Vermont State Disaster History." FEMA | Federal Emergency Management Agency. N.p., 22 May 2012. Web. 12 May 2012. http://www.fema.gov/news/disasters_state.fema?id=50.

Field, C.B., V. Barros, T.F. Stocker, D. Qin, D., Dokken, K.L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. Allen, M., Tignor, and P. M. Midgley, eds. *Climate Change Adaptation*. Cambridge, UK: Cambridge University Press, 2011.

"Find Assistance." DisasterAssistance.gov. Web. 1. Mar. 2012. http://www.disasterassistance.gov/.

"Fluvial Erosion Hazard Areas: Frequently Asked Questions and Answers." Vermont River Management Program: Vermont Agency of Natural Resources. 2010. Web. 1 Mar. 2012. http://www.vtwaterquality.org/rivers/docs/rv_vtfehqa.pdf.

Galloway, Anne. “Transportation Bill Clears Final Hurdle; VTrans to kick it into high gear.” VTDigger.org. 17 November 2011. Web. 1 Mar. 2012. http://vtdigger.org/2011/11/17/transportation-bill-clears-final-hurdle-cap-lifted-on-disaster-aid-to-vermont/.

Ganderton, Philip T. “Benefit-Cost Analysis of Disaster Mitigation: A Review”. *Mitigation and Adaptation Strategies for Global Change Special Issue: International Perspectives of Mitigation of Natural Hazards and Disasters* (2006): 1-28. Print.

“General Circulation Model (GCM) Data Portal.” International Centre for Tropical Agriculture (CIAT). Web. March 2012. http://www.ccafs-climate.org/.

Governors’ Institute on Community Design. Web. 1 Mar. 2012. www.govinstitute.org.

Gram, Dave. “Vermont Wind Federal Change on Guard Disaster Aid”. *The Associated Free Press*. Published in the *Burlington Free Press*. Web. April 2012.

Gray, Roxanne and Kristen Sailer. “FEMA’s Benefit Cost Analysis.” *Mitigation Planning Resources,* Wisconsin Emergency Management. 2010. Web. 1 Mar. 2012. http://emergencymanagement.wi.gov/mitigation/resources.asp.

Green Mountain Care. Vermont Agency for Human Services. Web. 1 Mar. 2012. https://greenmountaincare.vermont.gov/.

“A Guide to Federal Disaster Assistance.” The Ferguson Report. Web. 1 Mar. 2012. http://www.colliergov.net/modules/ShowDocument.aspx?documentid=18794.

“Hancock, Vermont, New England, USA.” *Virtual Vermont*. Web. March 2012. http://www.virtualvermont.com/towns/hancock.html.

“Hurricanes and Tropical Storms 2011 (Hurricane Irene)”. *The New York Times.* 8 Oct. 2011. Web. April 2012. http://topics.nytimes.com/top/reference/timestopics/subjects/h/hurricanes_and_tropical_storms/index.html?scp=1&sq=irene%20damage&st=cse.

“IPCC, 2011: Summary for Policymakers.” In: Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Field, C.B., Barros, V., Stocker, T.F., Qin, D. Dokken, D., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.-K., Allen, S., Tignor, M. and P.M. Midgley (eds). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

"Irene." Vermont Agency of Transportation. Web. 10 May 2012. <http://www.aot.state.vt.us/Irene/Irene>. Special Report on Managing the Risks of Extreme Events and Disasters to Advance.

“Irene Storm Event Maps.” VTRANS. 1 Mar. 2012.

Jaquith, Shayne. Personal Interview. 10 Apr. 2012. VT DEC River Management Program.

Kline, Mike, and Kari Dolan . "Municipal Guide to Fluvial Hazard Mitigation." www.vtwaterquality.org. N.p., 10 May 2010. Web. 4 May 2012. <www.vtwaterquality.org/rivers/docs>.

Knutson, Thomas R. “Global Warming and Hurricanes.” National Oceanic and Atmospheric Administration Geophysical Fluid Dynamics Laboratory. Web. March 2012. http://www.gfdl.noaa.gov/global-warming-and-hurricanes.

“Landscape Change Program.” University of Vermont. Web. March 2012. http://www.uvm.edu/landscape/menu.php.

Leno, James. Personal Interview. 9 Apr. 2012. Hancock Road Commissioner.

Lin, Ning, Kerry Emanuel, Michael Oppenheimer, and Erik Vanmarcke. "Physically Based Assessment of Hurricane Surge Threat Under Climate Change." Nature Climate Change 1389 (2012): Online.

Luxenburg, Roland. Personal Interview. 10 Apr. 2012. Hancock FEMA Project Specialist.

Lynds, Larry. Personal interview and Plymouth road tour. 12 April 2012. Plymouth Road Foreman.

Mallette, Eric, and Lyz Tomsuden. I am Vermont Strong. State of Vermont, 2011. Web. 1 Mar. 2012. http://www.vtstrong.vermont.gov.

“Middlebury River/ Vermont Route 125 Benefit-Cost Analysis.” Prepared by Landslide, Inc. and Milone & MacBroom for Addison County Regional Planning Commission. Print. 2010.

"National Weather Service Forecast Office - Burlington, Vermont." National Weather Service Eastern Region Headquarters. N.p., 2 Sept. 2011. Web. 12 May 2012. http://www.erh.noaa.gov/btv/events/Irene2011/.

Nemethy , Andrew. "Emergency gravel extraction raises questions about long-term changes to state's rivers." VTDigger.org: Independent, investigative news for Vermont. N.p., 15 Oct. 2011. Web. 12 May 2012. http://vtdigger.org/2011/11/15/gravel/.

NOAA "The 1927 Flood." The National Weather Service . N.p., 1 Aug. 2007. Web. 12 May 2012. http://www.erh.noaa.gov/btv/events.

NOAA "Storm Events Database | National Climatic Data Center." NCDC. N.p., n.d. Web. 12 May 2012. http://www.ncdc.noaa.gov/stormevents/.

“Options for State Flood Control Policies and a Flood Control Program.” Prepared by Vermont Agency of Natural Resources, Department of Environmental Conservation, Water Quality Division. Web. 1999. http://www.vtwaterquality.org/rivers/docs/rv_act137.pdf.

Page, Candace. "The Tweed after Irene: How to repair a ruined river." "www.burlingtonfreepress.com." N.p., 15 Jan. 2012. Web. 12 May 2012.

"Patrick Leahy, United States Senator for Vermont." United States Senate. Web. 1 Mar. 2012.

"Peter Welch, U.S. Congressman." Online Office of Congressman Peter Welch. Web. 1 Mar. 2012.

"Precipitation and Storm Changes." United States Environmental Protection Agency. Web. March 2012. http://epa.gov/climatechange/science/recentpsc.html.

"Rochester, Vermont." Town of Rochester. Web. March 2012. http://www.rochestervermont.org/.

Ring, Wilson. "Flooded Rochester Struggles to ID Cemetery Remains." *Burlington Free Press*. 12 Oct. 2011. Web. 26 April 2012. http://www.burlingtonfreepress.com/article/20111012/NEWS07/111012029/Flooded-Rochester-struggles-ID-cemetery-remains.

Schultz, S.D., and J.A. Leitch. "The feasibility of restoring previously drained wetlands to reduce flood damage." *The Journal of Soil and Water Conservation* 58(2003): 21-29. Print.

Staats, Jen. ENVS 401 Lecture. Middlebury College: Middlebury, Vermont. 8 March 2012.

"Stafford Act and Its Relation to the National Environmental Policy Act". U.S. Federal Emergency Management Association. U.S. Department of Homeland Security. Web. 1 Mar. 2012. http://www.fema.gov/pdf/about/stafford_act.pdf.

Stager, Curt and Mary Thill. "Climate Change in the Champlain Basin." The Nature Conservancy. May 2010.

Straus, Larry. Personal Interview. 17 Apr. 2012. Rochester Road Commissioner.

Swift, Ethan. Personal Communication. 2012. Vermont Rivers Program, Watershed Coordinator.

"Transportation bill clears final hurdle; VTrans to kick into high gear." VTdigger.org. Web. 1 Mar. 2012. http://vtdigger.org/2011/11/17/transportation-bill-clears-final-hurdle-cap-lifted-on-disaster-aid-to-vermont/.

"Two Rivers-Ottauquechee Regional Commission." Two Rivers-Ottauquechee Regional Commission. Web. April 2012. http://www.trorc.org/index.html.

USDA. "Vermont Fact Sheet: VT" USDA Economic Research Service - Home Page. N.p., 22 May 2012. Web. 12 May 2012. <http://www.ers.usda.gov/StateFacts>.

"USGS Water Information, Vermont." USGS Water Resources . N.p., n.d. Web. 12 May 2012. <http://md.water.usgs.gov/publications/wsp-2375/vt/index.html>.

U.S. Department of Agriculture. Web. 1 Mar. 2012. http://www.USDA.gov.

U.S. Department of Health and Human Services. Web. 1 Mar. 2012. http://www.HHS.gov.

U.S. Department of Housing and Urban Development. Web. 1 Mar. 2012. www.hud.gov.

U.S. Internal Revenue Service. Web. 1 Mar. 2012. http://www.IRS.gov.

U.S. Department of Transportation. Web. 1 Mar. 2012. http://www.DOT.gov.

U.S. Department of Treasury. Web. 1 Mar. 2012. www.Treasury.gov.

U.S. Federal Emergency Management Association. Web. 1 Mar. 2012. http://www.FEMA.gov.

U.S. Small Business Association. Web. 1 Mar. 2012. http://www.SBA.gov.

Vermont Agency of Natural Resources. Web. 1 Mar. 2012. www.anr.state.vt.us.

Vermont Disaster Relief Fund. Web. 1 Mar. 2012. http://www.Vermont211.org

“Vermont Better Backroads Manual.” Northern Vermont & George D. Aiken Resource Conservation and Development (RC&D) Councils. 3rd ed. 2009. Print. http://www.nvtrcd.org/custom-2/2009%20Better%20Backroads%20Manual.pdf.

"Vermont Rebounding Quickly From Hurricane Irene." New York Times 5 Dec. 2011: n. pag. http://www.nytimes.com. Web. 12 May 2012.

“Vermont Watersheds.” UVM. Web. 1 Mar. 2012.

"VTrans’ Irene Google Map Transitions to 511 | The Official Website of the Governor of Vermont." Governor Peter Shumlin | The Official Website of the Governor of Vermont. N.p., 18 Oct. 2011. Web. 12 May 2012. <http://governor.vermont.gov/newsroom-vtrans-irene-google-map-transitions-511>.

Whitehead, J. C., and A. Z. Rose. “Estimating environmental benefits of natural hazard mitigation with data transfer: results from a benefit-cost analysis of Federal Emergency Management Agency hazard mitigation grants.” *Mitigation and Adaptation Strategies for Global Change* 14 (2009): 655-676. Print.

Appendix A: Rochester Town Road Damage Costs

Compiled from Annual Town Reports (1938-1998) and from FEMA Project Worksheets (2008-2011)

Road Name	*Road #*	*1938*	*1973*	*1976*	*1998*	*2008*	*2011*	*Total*
Bethel Mt.	1		damaged					
Little Hollow	2		$846.45	$1,103.78	damaged		$112,463.33	$114,413.56
Steventon	2			$182.21				$182.21
Quarry Hill	3						$28,351.66	$28,351.66
Quarry Bridge	(26)			$43,836.92				$43,836.92
Rummel Road	4			$206.97	damaged			$206.97
Town Line	5		$1,202.50	$476.33	damaged			$1,678.83
Fiske	6		damaged	$499.00	damaged			$499.00
North View Drive	7				damaged	$2,098.06	$28,594.28	$30,692.34
Griggs	8		$75.40	$412.77				$488.17
North Hollow Rd	8					$3,107.82		$3,107.82
Marsh Brook	9				damaged	$9,267.20	$136,342.00	$145,609.20
Old Dump	9		$1,854.90					$1,854.90
Little Hollow	10		$1,261.17					$1,261.17

Road Name	*Road #*	*1938*	*1973*	*1976*	*1998*	*2008*	*2011*	*Total*
Reservoir Hill	15			$521.40				$521.40
Brook Street	15				damaged		$123,730.79	$123,730.79
Cyaara	17						$9,964.26	$9,964.26
Beans Bridge Road	18					$6,145.38	$6,668.38	$12,813.76
Beans Bridge	(29)			$4,607.50				$4,607.50
Middle Hollow	19						$12,218.22	$12,218.22
Bingo Road	20					$32,507.88	$33,908.00	$66,415.88
River Brook Rd. & Dr.	21							
Maple Hill	21					$5,160.91	$82,876.01	$88,036.92
Cooper Run	25		damaged				$23,506.83	$23,506.83
Moose Run	26		damaged				$14,357.01	$14,357.01
Jerusalem Hill/S Hollow	27		damaged		damaged			
Bingo Rd	28				damaged	$34,193.33		$34,193.33
Pine Gap	29					$31,775.00		$31,775.00
Pine Gap Road Bridge	(1)					$324,482.00		$324,482.00

Road Name	*Road #*	*1938*	*1973*	*1976*	*1998*	*2008*	*2011*	*Total*
Maple Hill	31			$195.46	damaged			$195.46
Austin Hill	33		$1,189.75	$280.69				$1,470.44
Clay Hill	34				damaged			
State Garage Road	35				damaged		$2,645.48	$2,645.48
West Hill Road	37						$49,666.06	$49,666.06
Babcock's	39		$1,167.53					$1,167.53
Wing Farm	39					$2,248.50	$2,888.54	$5,137.04
Corporation	40						$9,954.40	$9,954.40
Corporation Bridge	(25)		$6,061.91					$6,061.91
Liberty Hill	42			$216.71	damaged		$44,955.65	$45,172.36
Liberty Hill Bridge	(35)		$5,736.84					$5,736.84

Road Name	*Road #*	*1938*	*1973*	*1976*	*1998*	*2008*	*2011*	*Total*
Somers Road	43			$438.44				$438.44
New Boston	46						$12,456.48	$12,456.48
Peavine Drive	52					$2,548.03	$2,585.92	$5,133.95
Robert's - Rockerfeller	61		$3,716.20					$3,716.20
Donnet	61			$261.44	damaged			$261.44
Mt View Ln	68						$6,970.89	$6,970.89
Pine Gap	68							
Pine Gap Road Bridge	(2)					$289,542.55		$289,542.55
Edwins Pond	71						$6,970.89	$6,970.89
Total		**$10,235**	**$23,555.20**	**$53,239.62**	**$22,341.93**	**$743,076.66**	**$752,075.08**	

Appendix B: Plymouth Town Road Damage

Compiled from historical photographs and the first-hand knowledge of Town Road Foreman (Larry Lynds)

Structure	Bridge Number	Latitude	Longitude	Years Flooded	Notes
Rt. 100		43.53826306	-72.74535251	1973, 1976, 2011	Houses may get buyout because of photo evidence of repeat damage
MacDonald Rd.	Bridge 35	43.53739788	-72.74411081	1973, 1976, 2011	1973 bridge abutments are in the river upstream from the bridge
Dead End Rd	Bridge 34	43.52985115	-72.73932215	1973, 2011	See picture
Paillie Bridge	Bridge 55	43.52572775	-72.73559773	1973, 2011	Future strategy for securing the bridge may include using cables to anchor the bridge to pickup point upstream to prevent the bridge from floating downstream during floods
Paillie Bridge	Bridge 56	43.51871244	-72.73243876		
Rt. 100		43.5152808	-72.73173451	1973, 1976, 2011	
Frog City Rd.		43.50281247	-72.72436682	1973, 2011	
Rt. 100		43.500329	-72.71822465	1973, 2011	
Patch Brook/ Ninivah		43.4759851	-72.72503763	1973, 2011	
Patch Brook/ Ninivah		43.47619196	-72.73027522	1973, 2011	
Patch Brook/Ninivah		43.47656714	-72.73299289	1973, 2011	

Structure	Bridge Number	Latitude	Longitude	Years Flooded	Notes
Patch Brook/ Ninivah		43.47514456	-72.73957754	1973, 2011	
Townsend Barn Rd.		43.47480442	-72.74495982	1973, 1976, 2011	
Dublin Rd.		43.4759219	-72.74851383	2011	
Library Rd.		43.46580519	-72.7057025	1973, 2011	Town is considering declassifying to a trail (currently a class 3 road) and building a footbridge to connect the Inn and library to the general store.
Kingdom Rd.		43.46511411	-72.70510563	1973, 2011	1st Kingdom Rd. photo taken here.
Kingdom Rd.		43.46902334	-72.69185669	1973, 2011	
Gilmore Rd.		43.47122971	-72.68308637	2011	
Kingdom Rd.		43.47034743	-72.68263207	1973, 2011	Culvert is too small diameter; unfortunately, FEMA only pays for culverts that are one size up, e.g. 18" to 2'. Kingdom Rd. culverts were recently upgraded to smooth-bore plastic because they take more flow than corrugated bore plastic or concrete (reduced friction).
Lions Hill and Five Corners		43.46957034	-72.69312168	1973	
Access Road (not sure of the name)		43.52651431	-72.67758926		
Bridge 38	Bridge 38	43.53451928	-72.67058233	1973, 2011	FEMA wants to rip-rap up and downstream of this bridge.

Structure	Bridge Number	Latitude	Longitude	Years Flooded	Notes
Apple Hill		43.53411594	-72.66416959	1973, 2011	
McCoee Rd. (spelling is questionable)		43.5472928	-72.65779917	1973, 2011	
Culvert	Culvert	43.55040156	-72.65780956	1973, 2011	Local resident moved all of the gravel from the washed out culvert by hand back to the river
Rt. 100a	Bridge 8	43.55897533	-72.66544682	2011	As a result of this bridge washout, Rt. 100a did not open for a month after Irene.
Rt. 100a		43.55691053	-72.70630667	1973, 2011	
Rt. 100a		43.55034339	-72.70956631	1973, 2011	As a result of this bridge washout, Rt. 100a did not open for a month after Irene.

4. Behaviors and Motivations of Vermont Residents in the Wake of the Flood

Ali Andrews, Alyssa Crews, Evan Deutsch, Hilary Platt, Nial Rele, Maria del Mar Rojas, Molly Rosenblatt

I. Introduction

Tropical Storm Irene caused widespread devastation throughout the state of Vermont. The August storm killed three individuals, isolated thirteen communities, and damaged over 500 miles of roads, 200 bridges, and 1,500 homes.[1] While the previous two chapters in this report have explained Tropical Storm Irene's effects on Vermont's landscape and infrastructure, this chapter discusses the human side of the storm through the Vermonters it affected. Our primary research goal was to understand the motivations and behaviors of Vermont residents during the storm and throughout the recovery process in order to inform the creation of future disaster recovery policies in the state. We wanted to know what motivated residents to live in potentially dangerous areas and how they made decisions regarding whether or not to remain in their current residences despite risks of future damage.

Historically, Vermont towns were established along waterways, as rivers provided a source of power and a means of transportation.[2] Living next to a river was convenient and essential in the transportation of timbers and other goods as well as a source of power for mills and factories. With the growing number of extreme rain events in the state projected by climate change models, however, the placement of Vermont towns has become increasingly unsafe.[3] Homes and communities next to Vermont waterways are in danger of flood damage, and complete destruction in extreme cases. Vermont climatological data indicate that flooding is a byproduct of global climate change and the

[1] Starting Over Strong Vermont. "News and Press Releases." http://startingoverstrongvermont.org/?page_id=22, visited May 2, 2012.
[2] Smart Growth Vermont. "Historic Settlement Patterns." http://www.smartgrowthvermont.org/learn/patterns/, visited May 1, 2012.
[3] Vermont Agency of Natural Resources. "Tropical Storm Irene: By the Numbers." http://www.anr.state.vt.us/anr/climatechange/irenebythenumbers.html, visited May 2, 2012.

severity of storms will only increase with time. Given the dangerous location of residences and predictions of future flooding, our project sought to understand how the state of Vermont could ensure safety for its citizens during future flood events. In order to inform policy makers, we believed it was most important to understand the behaviors and motivations of current residents. We looked to answer questions, such as: How well informed are residents about the risks of flooding? Are residents afraid of future flooding? If informed of the dangers of future flooding, would residents be willing to relocate?

In order to answer these questions and create a more informed picture of the behaviors and motivations of Vermont residents, we first turned to behavioral psychology research on floodplain residents. We used the information from this research to inform our creation of survey and interview questions. We focused our research in three towns that were significantly affected by Irene—Hancock, Rochester, and Plymouth. We disseminated our surveys in each of these towns and conducted personal interviews.

Key themes emerged during our analysis of these surveys and interviews. We used these themes to create strategic policy recommendations for the state. We believe that policies that take into account the behaviors and motivations of citizens will have the most successful implementation. If the state creates policies that reflect the wants and needs of its citizens, it will have the greatest possibility of keeping citizens safe when the next flood comes.

II. Methodology

A. Background Research

Before commencing our interviews and distributing our surveys, we began our study with background research on the behavioral psychology of residents in disaster areas, in addition to research on the Vermont residents impacted by Tropical Storm Irene. The research process focused on several studies by psychologists such as Waterstone, Sim and Baumann, and Helsloot and Ruitenberg, focusing on citizen response to general disasters and natural hazards, to specific literature on the behavior of floodplain residents. Through these articles we began to understand the motivations and behaviors of many

floodplain residents—how they coped with damage, why they chose to live where they lived, and whether they moved or stayed in the wake of the flood.

Although the information provided by the literature on the psychology of disaster described the motivations and expected reactions of the general public, it lacked the immediate context specific to Vermont in the wake of the tragedy of Irene. Our next step in the formulation of our surveys was to look at local media concerning Irene recovery. Newspapers, blogs, and radios provided stories of many Vermont residents whose homes were destroyed, whose businesses were hurt, and whose lives were ultimately affected by the storm. The narratives recorded by the media allowed for more personal and specific insights for our formulation of the profile of a "Vermont resident in an affected area."

The stories of Vermont residents in the wake of Irene revealed several areas in the state hit particularly hard by the storm. We prioritized these towns when selecting areas to conduct personal interviews and surveys. Additionally, we researched the demographics of towns with extensive damage in an attempt to choose areas with demographics representative of the rest of the state. On reading the narratives of many residents and looking at the demographic data, we decided to focus our efforts on Hancock, Rochester, and Plymouth.

Figure 1. Home destroyed near downtown Rochester. Photo by Mansfield Heliflight.

B. Survey and Interview Development

From our research on disaster psychology and an understanding of our focus areas, which we detail in forthcoming sections, we developed interview and survey questions. We visited the Plymouth, Hancock and Rochester areas to conduct individual interviews and distribute surveys.

We were referred to individuals for interviews by word of mouth, which was appropriate in the small towns where we worked. Without any contacts in Plymouth, we first met a postal worker who referred us to the wife of a selectboard member who graciously called several people on our behalf. Without the openness and generosity of the populations of our focus areas, we would not have been able to gain as many perspectives as we did. We conducted detailed interviews with residents who were significantly affected by Irene, as well as individuals involved in the rescue, repair and rebuilding efforts during and after the storm.

Figure 2. Rt. 100A in Plymouth, VT. Photo by Mansfield Heliflight

In order to reach a broad subject base in our focus areas, we developed a survey with similar questions to those used in the interviews but these questions prompted more concise and precise answers. We distributed about 30 surveys in each focus area in the mailboxes of residences in low-lying or potentially affected areas. The response rate for these surveys was fairly low; thus, we also spent one afternoon in the center of the town of Rochester canvassing and gained an additional 10 responses.

C. Data Analysis

We first organized the data that we collected from the interviews and surveys into qualitative and quantitative categories. The quantitative category helped inform our understanding of the extent of the impact that Tropical Storm Irene had in our study areas. It also helped us understand how residents have responded to the damage caused by Irene and the resultant flooding. We organized our quantitative data into visualizations such as pie charts and bar graphs.

The qualitative data provided us with an insight into the psychological effects of the storm. We also drew from outside research and other sets of interviews. We then proceeded to draw out significant themes from the interviews and surveys that informed our policy recommendations related to the social and psychological effects of Tropical Storm Irene.

III. Demographics of Focus Areas

To establish a quantitative understanding of the sociology of our focus areas, we compared census information of each town to the statistics of the greater State of Vermont. Based on our readings and class discussions, we acknowledge that socioeconomic status can play an important role in one's level of vulnerability and ability to respond. To measure socioeconomic status we used income per-capita and income per-household as indicators. In terms of per-capita income, all research areas were below the state average. By income per house, Hancock is well below the state mean, while Plymouth is actually greater than the mean. Race proved not to vary significantly enough to merit further research for this project. Based on our research on the psychology of disaster, we believe that age may play a role in the psychological and physical responses of residents. We used percentage of population over 65 years and median age as indicators of the elderly populations in our areas of interest. This research showed that both focus areas are above the state mean in elderly populations. These quantitative indices of our focus areas proved useful in being able to apply what we learned more qualitatively to the state as a whole. All information is from the US Census Bureau Fact Finder (Table 1).

Figure 3. Destroyed Land Near Hancock, VT. Photo by Mansfield Heliflight

Area	Income			Age	
	Per capita	Per house	% below poverty line	% over 65 years	Median age
Vermont[4]	$27,478	$51,841	11.1%	14.6%	41.5
Hancock[5]	$20,426	$32,500	23.8%	17.0%	48.3
Plymouth[6]	$22,788	$58,333	5.3%	21.8%	50.8
Rochester[7]	$26,155	$58,253	7.6%	20.2%	50.1

Table 1. Income and Age Data for Vermont and our Focal Areas.

[4] US Census Bureau. "Profile of General Population and Housing Characteristics: 2010, Vermont" and "Selected Economic Characteristic: 2006-2010, Vermont." http://factfinder2.census.gov, visited May 12, 2012.

[5] US Census Bureau. "Profile of General Population and Housing Characteristics: 2010. Hancock town, Addison County, Vermont" and "Selected Economic Characteristic: 2006-2010. Hancock town, Addison County, Vermont." http://factfinder2.census.gov, visited May 12, 2012.

[6] US Census Bureau. "Profile of General Population and Housing Characteristics: 2010. Plymouth town, Windsor County, Vermont" and "Selected Economic Characteristic: 2006-2010. Plymouth town, Windsor County, Vermont." http://factfinder2.census.gov, visited May 12, 2012.

[7] US Census Bureau. "Profile of General Population and Housing Characteristics: 2010. Rochester town, Windsor County, Vermont" and "Selected Economic Characteristic: 2006-2010. Rochester town, Windsor County, Vermont." http://factfinder2.census.gov, visited May 12, 2012.

IV. Survey Development

A. Psychology of Disaster Literature Review

In our literature review about the psychology of disaster we focused on disaster relief, specifically in the context of flooding and the individual decision-making process. We found three studies that were particularly relevant and useful during this process. A summary of the findings of each of these studies is below.

1. "Hazard Mitigation Behavior of Urban Floodplain Residents." *Institute of Behavioral Science, Boulder Colorado*.[8]

According to research conducted by the Boulder Institute of Behavioral Science, there are five key factors influencing residents' hazard mitigation actions:

1. The residents' previous experience of a hazard
2. How long the residents have lived in their homes
3. The age of residents
4. The residents' distance from flood-prone bodies of water
5. Whether residents have received easily digestible materials about flood dangers

In their research, the Boulder Institute examined how to improve residents' preparation for—and action during—floods. They found that floodplain residents who received targeted pamphlets explaining their unique risks as floodplain residents were more likely to take action. Individuals who were not aware that they were receiving specifically targeted information were less motivated to act.

2. "Educational Programs and Human Response to Natural Hazards." *Environment and Behavior*.[9]

Scholars John Sims and Duane Baumann addressed the complicated task of ensuring floodplain residents' safety. According to the authors, researchers must be willing to accept ambiguity when dealing with a situation like risk mitigation efforts.

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[8] Waterstone, Marvin. "Hazard Mitigation Behavior of Urban Floodplain Residents." *Institute of Behavioral Science, Boulder Colorado*. 1978.

[9] Sims, John H., and Duane D. Baumann. "Educational Programs and Human Response to Natural Hazards." *Environment and Behavior* 15:165. 1983.

Sims and Baumann's research provided a broader picture of the factors covered by the Boulder Institute. Key themes and findings were:

1. *Myth: Education will automatically lead to action.* Only under very specific conditions may awareness lead to action; however, it is not guaranteed. For example, a 1979 study looked at the influence of the dissemination of 670,000 floodplain maps. The maps had no effect on people's attitudes.
2. *Myth: People learn from experience.* Rather, hazard experience is only sometimes effective in influencing later mitigation efforts. Not all residents who have experienced previous hazards will take steps to prepare for the future.
3. *The psychological characteristics of residents influence their risk mitigation efforts.* Researchers must consider variations among residents' values, definitions of right and wrong, emotional investments in dreams, cognitive processes, and personalities.
4. *Residents' cognition characteristics influence their risk mitigation efforts.* Characteristics of cognition: Once people have formed opinions, they are unlikely to be changed; because estimating risk is discomforting, individuals try to simplify the issue and choose false solutions that do not require emotional stress. Individuals overestimate dramatic hazards and underestimate everyday hazards.
5. *There is a link between hazard behavior and individual psychodynamics.* Studies indicate that individuals with an internal locus of control (internal feelings of control) take hazard mitigation actions. Those who believed in an external locus of control (God/fate) were less willing to take or purchase flood insurance.
6. *There are keys to creating successful warnings for residents.* Warnings must be clear, explain the desired response in addition to the warning, come from a reliable, trusted source, and be reinforced locally and socially. Residents are more likely to listen to warning if they a) know their neighbors are also accepting the warning and b) come from the proper form of media—television is more effective at reaching individuals than radio.

3. Citizen Response to Disasters: A Survey of Literature and Some Practical Implications. *Journal of Contingencies and Crisis Management.*[10]

Helsloot and Ruitenberg also contributed to the scholarly work on the preparation and response of citizens during disasters in their work. Since the Second World War, disaster management was federally organized under the heading of civil defense. The underlying mentality was that disasters were the enemy; although "command" and "control" were the means to reduce the situation, they were not necessarily the most effective strategy. Citizens were seen as generally "rational" in their response to disaster but limited by federal laws and regulations and the information available. The key themes and findings were:

1. *Generally speaking, citizen response is what saves the day when disasters strike, but the act of preparation is an entirely different problem.* Citizens are the ones who provide most of the initial aid—they are very proactive once disaster strikes.
2. *Citizens usually act "rationally". If they do not witness authorities preparing for hazards, they too will not put resources into the preparation process.*
3. *"Sub-optimal" choices during disasters may be attributed to a) inadequate information to assess the situation or b) a sense of loyalty of citizens to those to whom they are close.*
4. *Both citizens and the government should work together and take advantage of the other's unique knowledge base. They should be in communication during all phases of disaster relief.*
5. *The tone of warning brochures may impact residents' safety mitigation efforts.* Information about disaster preparation is often in the form of concrete checklists that describe how to prevent accidents and what to do during disasters. The style and tone of the brochures, however, differs between countries. While the US illustrations depict happy and prepared families, a typical brochure in New Zealand shows a parent fleeing with a child with the line: "Will you cope when disaster strikes?" Further research needs to be done to assess the effectiveness of various forms of warning materials.

[10] Helsloot, I. and Ruitenberg, Citizen Response to Disasters: A Survey of Literature and Some Practical Implications. Journal of Contingencies and Crisis Management, 12: 98–111. 2004.

6. *Residents' varying perceptions of risk affects their safety mitigation efforts. Citizens are most likely to prepare for threats they perceive as "imminent."*

B. Survey and Interview Questions

Based on our current knowledge of the focus areas and our research, we formulated a list of questions to ask floodplain residents and business owners. We worked with the Vermont Folklife Center on useful guidelines for conducting interviews and reaching out to floodplain residents. Given their recommendations we made an effort to conduct all of our interviews in person, to cater each interview to the interviewee and the topics that he/she felt most comfortable discussing, and most importantly we focused on establishing our role as listeners. Most interviews were done in person, and responses and topics addressed were not completely uniform. The interview questions functioned as a baseline, but conversation was allowed to veer to new topics. While we tried to address each of the questions below during the personal interviews, we were respectful of our interviewees' time constraints and privacy.

We used the findings from our literature review to inform our interview questions. These questions were based on the key themes and issues identified in the studies we researched.

<u>Questions for residents and business owners</u>

- How long have you lived in your town?
- Are you aware of whether your house is located in a floodplain hazard zone?
- What do you believe caused the flooding?
- Do individuals in your community support floodplain protection efforts?
- What kind of damage did your home face during Irene?
- Has your home ever been damaged in a flood prior to Irene?
- Are you considering moving? If yes, why? If no, why not?
- Do you think that there is a possibility of another flood in the near future?
- What steps have you taken to prepare for another flood?
- How has your community responded to the event? What sort of support have you received or given in the short term? What has the long-term response been in

terms of rebuilding or providing compensation for damaged residences or businesses?

- Is there information that you wish you had when you purchased your home?
- What information was given to you when you purchased your home? Did you know if you were at risk? Would you have bought your house if you had known the risk?
- Do you know people who have already moved from the area? Do you know people who are planning to move from the area?

Although the comprehensive nature of personal conversation was ideal for gathering the information needed, surveys offered a means to reach more people in a limited period of time. We created a basic survey with fewer questions so that residents would be more willing to take the time to respond.

Survey Questions

- How long have you lived in your current home?
- How long have you lived in this community?
- Is your home located in a floodplain?
- Did your home face damage from Irene?
  If yes, please elaborate on the damage.
- Do you believe your home is in danger of future flooding?
  If yes, do you consider moving?
- On a scale of one to ten, how afraid are you of future flooding?
- Do you know people who moved from the area after Irene?
- Are your neighbors considering relocating due to Irene?
- Have you taken steps to prepare for another flood?
  If yes, please explain steps taken to prepare for future flooding.
- Do you believe you were given adequate government support following Irene?
  Please explain the support given to you.

These questions were also based on our research of the psychology of disaster victims and of residents in hazardous areas. According to research conducted by the Boulder Institute of Behavioral Science, the five factors that influence the preparedness and effort of individuals in the formulation of a hazard mitigation plan are: whether the residents have previously been in a hazard; how long the residents have lived in their homes; the age of the residents; the residents' distance from flood-prone bodies of water; and whether they have received easily-digestible materials about flood dangers.[11]

Our questions stemmed from these factors, excluding age, which we estimated during our interviews, as it seemed a difficult topic to smoothly broach in a casual conversation. Additionally, the form of hazard information received by the resident influences his behavior.[12] We inquired about the opinions, protection, and response efforts of the community in order to find parallels between community and individual behavior.

An important conclusion is that education does not equal action.[13] People don't necessarily learn from experience. In an attempt to understand their outlooks on flood occurrence and repeat destruction, we asked our interviewees whether their houses were damaged prior to Irene. As determined in the Helsloot and Ruitenberg study, the perception of the risk at hand affects the preparedness of the residents—whether the event has "catastrophic potential" or is a "perceived threat."[14] According to Helsloot et al, residents only prepare for threats that they perceive as "imminent;" thus, it is critical to ask whether our interviewees believe that another flood will occur in the near future.

Ultimately, however, to understand the mitigation process (or lack thereof) of residents in floodplains, we must first understand the residents themselves: their values, definitions of right and wrong, emotional investments in dreams, cognitive processes, and how these dimensions of personality influence hazard behavior. We tailored our interviews to reveal these personal principles.

[11] Waterstone, Marvin.1978.
[12] Sims, John H., and Duane D. Baumann.1983.
[13] Sims, John H., and Duane D. Baumann.1983.
[14] Helsloot, I. and Ruitenberg, A. 2004.

V. Interview Summaries

This section tells the stories of residents we interviewed. These interviews lasted anywhere from ten minutes to an hour. While some residents were energized to talk with us from the very beginning, others were more reserved and questioned the intention of our project. While we did have a set of questions that we hoped to have answered in the interviews, we allowed the interviewees to guide the conversations. Discussions about Irene, a storm that is still affecting many residents' daily lives, are emotional and personal. We sought to honor this during our interview process. We believe that it is essential for these narratives to be shared and respected in the wake of this disaster. While this section serves only to summarize our interviews, the subsequent sections will explain the themes that emerged from these stories and how they can be beneficial in the creation of future disaster recovery policies in the state.

Figure 4. Echo Lake Inn.

Lawrence Jeffries, Echo Lake Inn Owner: Plymouth, Vermont (April 5, 2012)

Lawrence Jeffries is the owner of the Echo Lake Inn in Plymouth.[15] Although not a native Vermonter, Jeffries's life and livelihood are rooted in the management of the Inn, which caters to many tourists during late summer, fall foliage season, and the ski season. A man over 60, Jeffries believes that a flood comparable to Irene will not again occur in his lifetime. He has invested in the repair of the basement of the Inn, which includes the restaurant, bar, and 2,400 square feet of storage and service space. Jeffries stated, however, that he has not replaced the $13,000 worth of wine he lost in the flood. In the

[15] Jeffries, Lawrence. (2012, April 5). Personal Interview.

event of future floods, he noted, "I don't have as many wines as I used to have, and I'm not buying many because it could happen again." In addition, while Jeffries believed that there is little he personally could do to prepare for future flooding, he hoped that the state would dredge the river "to prevent these floods." Jeffries continued throughout the interview to state contradictory comments in reference to flood preparation and disbelief of future storm damage.

Jeffries had flood insurance that paid for part of the damage. He explained, "The insurance paid for a new washer dryer, to rebuild the furnace, to put new sheetrock in, and for some cleanup. But anything to do with the restaurant downstairs and the 2,400 square feet of storage was not covered." The wine, the $7,000 worth of stainless steel refrigeration, the furniture, and any other items actually stored in the basement space were not included in the policy.

Larry Lynds, Road Foreman: Plymouth, Vermont (April 5, 2012)

Larry Lynds is the Road Foreman and the Emergency-911 Coordinator at the Plymouth Town Office.[16] He was involved in the initial rescue and repair efforts. As a long time Plymouth resident, Larry remembers the 1973 flood. Following Tropical Storm Irene, Larry explained, people he knew who moved did so because of the irreparable damage to their homes. "Some of the residents would have loved to make repairs, but the damage was so bad that they didn't have the option," he explained.

Touching upon the topic of government aid, Lynds explained that many of the damaged homes were secondary residences, and thus did not qualify for FEMA aid. Similarly, homes with basement damage were also exempt from aid. The "floodplain" designation is hazy, Lynds explained. He mentioned a fellow Plymouth resident Susan Mordecai who, despite the complete destruction of her house, was not offered a buyout because her home was not technically in the "floodplain." Mordecai's home had also suffered severe damage in the 1973 flood. Once she was able to prove that her home had been damaged during the 1973 flood, FEMA offered assistance.

[16] Lynds, Larry. (2012, April). Personal Interview.

Figure 5. Rt. 100 Road Washout, Plymouth VT: by Michelle Pingree

Betty and Bill Jarvi, Retired Residents: Plymouth, Vermont (April 5, 2012)

Betty and her husband discussed both their history as Vermonters as well as the damage Tropical Storm Irene wreaked on the Echo Lake recreation area.[17] Betty lived in Vermont from age 2 ½ to 8, when her parents moved her back to New Jersey. From then onward she was a summer resident until she met her husband Bill, who was a bell-hop at the Echo Lake Inn. Since then, Betty and Bill have remained in Plymouth. Bill's family moved from the Bronx to Plymouth when he was 2 years old, when his father "struck up the deal of the century", trading his Model T for a 160 acre farm and farmhouse. The farm was sold at the end of World War II and the parents moved down the street.

As far back as Betty can remember living in the area, there have not been any floods comparable to Irene or the 1927 flood. There have been local floods, particularly in the Ludlow area, as she noted: "You'd get little bumps that would wipe out a road or two but nothing like this flood." She says the financial impacts of Irene have been severe, particularly for Echo Lake residents who rely on income from summer rentals to survive the winter. Massive amounts of sediment and water flowed off the hills and into the lake, contaminating the water supply and making the lake unsuitable for recreational use this summer. Although Echo Lake State Park will be reopened, no fishing or swimming will be allowed in the lake: "It [Irene] certainly has had its impact along with the financial recession up here. It's been pretty hard here because our lake is not pristine and clear. Now it's all brown and green and yucky."

[17] Jarvi, Betty and Bill. (2012, April 5). Personal Interview.

Michelle Pingree, Town Lister: Plymouth, Vermont (April 5, 2012)

As one of the Town Listers in Plymouth, Michelle was involved first hand in the emergency response to Tropical Storm Irene.[18] She expressed great satisfaction with the speed at which people of the town responded and the community spirit. She knows people that have been forced to move and understands the risks of being located in a floodplain. Her own property was damaged, and the town required her to purchase a 100-year flood culvert at her own expense. Pingree explained that flood insurance is not really something that most people consider. Generally speaking, she was not impressed with FEMA or government assistance.

"Mom and Dad, they're having a hard time letting go," Pingree explained, referring to the destruction of her parents' home. "They lived there for sixty years and raised four kids. It's very hard for them to move on." Despite the traumatic experience, Pingree said that she has definitely learned from the disaster. "We're good to go," she proudly said. "We've learned our lesson, and we're more prepared now in case of another disaster. There are still a lot of things that still need to happen. It taught me to never underestimate the power of nature."

Figure 6. Pingree Sugarhouse 4/5/2012.

Caroline Meather, Librarian: Rochester, Vermont (April 12, 2012)

Caroline Meather and her husband have lived in the town of Rochester for thirty years.[19] They have raised their two daughters in that home, a home that was almost torn to the ground by Irene. Caroline's home and her husband's electronic design business,

[18] Pingree, Michelle. (2012, April 5). Personal Interview.
[19] Meather, Caroline. (2012, April 12). Personal Interview.

located in their basement, were both greatly impacted by the events that took place during Tropical Storm Irene. The collapse of her neighbor's house made national headlines. Caroline's home narrowly survived the same fate because her neighbor's collapsed house forced the water to change its path. Although Caroline's home was considered to be in a floodplain she expressed that she could never have predicted that her "tiny little babbling brook would turn into a torrent." The flooding destroyed her entire basement, left her first floor partly destroyed under the heavy weight of mud, and almost took the life of her neighbor as his house caved in while he was still inside. They were especially unprepared because they had never had problems with flooding before. Caroline even mentioned that her house had escaped the flood of 1927 without any damage. The fact that her neighbor's house, which was only 10 feet away from hers, was not considered to be in a floodplain, yet was completely destroyed during Irene, serves as a ruthless reminder of how unpredictable these flooding events can be.

Caroline described how the rivers had changed and expressed anxiety over what this would mean for future flooding. In her interview she shared these worries: "The rivers are not what they used to be before. The river next to our house used to be at least 12 ft deep. It's filled in now. They dug it out some but we probably have about six feet, so it's half of what it could take of water...I'm concerned about it." Despite these concerns of future flooding Caroline and her husband were fixing up the house and had no plans to move. Part of their reason to stay has to do with the location of their business. Having their business in their home also means that they have received no help from FEMA, which only helps residential housing. The only option offered to them comes in the form of loans from the Small Business Administration or VEDA (Vermont Economic Development Authority), a loan that they are not sure they'll be able to pay back. In order to have access to these loans, however, they must first acquire flood insurance, a task which has proved much more difficult than expected. Caroline was finally able to get flood insurance nearly eight months after she had submitted her application.

Cathy Curtis, Town Clerk: Hancock, Vermont (April 12, 2012)

Cathy Curtis is the Town Clerk in Hancock and has held the position for a little longer than a year.[20] Cathy says she was lucky that a nearby bridge being washed out was the only direct impact of the floods to her livelihood. She talked about her neighbors who did not live, literally and figuratively, on the "right" side of the road. Just due to a small gradient, Cathy's home was safe from the water but her neighbors across the street were affected quite badly. When asked if she was concerned that her home would be impacted by a future flood, she responded that she was concerned of that but if that were to be the case, then her neighbors would have had water "halfway up their houses."

Cathy's neighbors had not considered that their home was in the floodplain. But now they are certain that those homes are in the floodplain and in danger of repeated damage from future floods. Although they harbor this concern, the neighbors seem unwilling to move. A couple of people were looking for different property. Hancock has suffered from 3 floods in the last 13 years. Though there was an awareness of "weather changing all over the country and the world," and climate change had been mentioned in town conversations, Cathy was hesitant to represent the whole town in her assessment of the causes of the flood.

She was clear that Hancock was not exempt from future flooding and that they were in a state of "no control" during floods. Cathy talked about how across the state, houses and sides of mountains washed away due to the immense magnitude of the flooding. As the Town Clerk, Cathy said that she maintained a good working relationship with FEMA. She heard complaints about how long they would take to process claims, but that "was just procedure." Although the cost of the repair work to the town was only 10%, as the state and FEMA covered the rest, Hancock does not have a large tax base, and they are probably going to have to raise taxes to pay for the damage. "It's going to take a few years" for the town to get back on track after the damage caused by Irene, says Cathy.

[20] Curtis, Cathy. (2012, April 12). Personal Interview.

Eric LaPorte, Recent Resident: Hancock, Vermont (April 12, 2012)

Eric LaPorte is a new transplant to Hancock.[21] He was living in Rutland in a friend's house and moved to Hancock after the storm to live in the Gathering Inn. He doesn't own property of his own but he described the damage experienced by community members. They were very happy with FEMA's response, saying they came back to a house multiple times to assess damage. He thinks that the community is vulnerable to future flood pointing to the bridges that were washed out, saying, "What if there's another flood? What would you have?"

He views Irene and similar storms as acts of God: "They think it's Mother Nature but it's God that will send the wrath in." "Why did Irene hit this region so badly? Pittsfield. Killington. Why? God created the mountains. Why did God allow all this?" The answer, he says, is: "wake up America and repent." LaPorte said "I've seen a lot of government officials since the storm," including officials from the state, FEMA and other government agencies, Eric opines; however, "nobody was equipped for this storm at all. Why? Because they didn't think it would happen in Vermont."

He doesn't believe mitigation efforts should be implemented because of the geography of the community: "Evacuation? Where are you going to run to? How are you going to help anybody? How much money is it worth?" Despite that statement, he doesn't think people will leave the community of Hancock, citing the long history of the town.

Susan Mordecai, Teacher: Plymouth, Vermont (April 15, 2012)

Susan Mordecai lived on Route 100 just north of the now-defunct elementary school.[22] She is a teacher for Special Education at a school about 40 miles away. Her home was completely destroyed in the flood and she now lives in a house she recently purchased about a mile away on the side of a hill.

She's lived in Plymouth 26 years, but in her previous home 6 or 7 years before Irene hit, she was told there was no risk of flooding here because her property wasn't considered to be in a floodplain. "As a matter of fact, the guy who I bought it from told me that it never flooded," said Mordecai. She thinks it will flood again in Plymouth but

[21] LaPorte, Eric. (2012, April 12). Personal Interview.
[22] Mordecai, Susan. (2012, April 15). Personal Interview.

she lives on a hill now so she is not as concerned. She moved because her house was ruined as was much of the property as well. Some of her neighbors were also not allowed to return to their homes as mandated by town administrators. “It’s all holes and gullies. A lot of the property washed away…The land was compromised” said Mordecai of the damage that prevented her from returning to her home. “The whole property was valued at 125 [thousand dollars]. Now it’s valued at 20.” She thinks that the climate is changing and it is probably related to human actions.

Figure 7. Susan Mordecai’s home on April 5, 2012. Photo credit Michelle Pingree.

She didn’t have flood insurance because she wasn’t technically in a flood zone. “I tried to get flood insurance when I realized that it does take on water but I was told that I couldn’t have flood insurance because I didn’t live in a flood zone,” said Mordecai. She got assistance from FEMA but nothing from the state. She was disappointed in Governor Shumlin’s and the state’s response. Mordecai described a visit from Governor Shumlin to her destroyed home a few days after the storm: “He[Governor Shumlin] asked me who I was. I said I’m a state employee, I’m a teacher. And so we’re in my backyard and I say, ‘Who cleans this up?’ and he said ‘You do.’ And I said ‘I’m not twenty. I can’t.’” She was happy with the rapidity with which FEMA sent her money and the sensitivity with which employees interacted with her about her loss. When asked how the state could have responded better or could change in the future, she said there wasn’t much to be done because “there’s no dress rehearsal for that.”

Sue and Al Poirier, EMS and Fire Department Volunteers: Plymouth, Vermont (April 17, 2012)

Plymouth Residents, Sue and Al Poirier are members of the town's fire department and Emergency Medication Services team.[23] While the Poiriers' home was not directly affected by Tropical Storm Irene, they both played an instrumental role during Irene and throughout the recovery process. On the day of the storm, Sue and Al came down from their house on a hill to assess the lakes in Plymouth. Once in the center of town, the couple realized that the flooding was substantial and that people's homes were in danger. They used their four-wheel-drive truck to pick up an elderly couple and several other residents whose homes were facing severe flooding. They noted that the elderly couple, who had lived in Plymouth almost their entire lives, was very hesitant to leave their flooding home.

The Poiriers set up a relief area at the fire station room, which is connected to the town clerk's office. They found food from a recent fire department gathering and collected sleeping mats at the nearby elementary school. The noises on the day of Irene were tremendous, Sue recalled, "It sounded like a thunderstorm because all the boulders were coming down the hill." Both she and Al had to keep an eye on their rescued residents who were eager to return to their homes for belongings. In the moment, residents were not able to grasp the severity of the situation.

Both Sue and Al commented on the amazing community-building that took place during the storm and recovery. Sue was especially impressed with a woman, Susan [Mordecai], who had lost her entire home during the storm. Although Susan had lost her house, she was offering to give her remaining items to Sue. She offered Sue both a dry T-shirt she had left in her car and her winter Ugg boots. Sue noted, "This is somebody that had lost everything and she was giving *me* her stuff." Also impressed with the community response, Al noted, "The 11 days after all of this happened…it was all for one and one for all…it was just a phenomenal thing."

The Poiriers had a positive experience with the outside relief that came to Plymouth. In the weeks following the storm, state police, FEMA, the National Guard, the Coast Guard, and the Air Force came to their town. Al explained that once these

[23] Poirier, Sue and Al Poirier. 17 April 2012. Personal Interview.

agencies knew that Plymouth had been hit badly, the town had "total support." He continued, "You couldn't complain. Between state police and National Guard, they all were extremely beneficial and helpful. And state police were here almost every day with us." Sue's only complaint, which she noted shouldn't even be a complaint, is that she wished the town had had more heavy equipment to aid in the road rebuilding process.

According to the Poiriers, Plymouth town members are not overly concerned about future flooding. Immediately after the storm, people were talking about being better prepared for the next storm; however, today they notice that most people do not believe a storm will occur for another 100 years and thus are not taking steps to prepare. Sue acknowledged that she believed weather patterns in Vermont are changing. She attributed this changing weather to global warming. In reference to global warming, Sue noted, "I don't believe it's man-made; I believe it happens naturally, you can see it at the Grand Canyon that there have been cycles like this."

She believes that town members should be shown pictures of this flood and previous floods that demonstrate the repeatedly damaged sites in the area. While Sue said that she "hates" government mandates, she did express that the government needs to ensure that individuals have flood insurance for their homes.

Beth and Bob Kennett, Liberty Hill Farms Owners: Rochester, Vermont (April 24, 2012)

Beth and Bob Kennett have owned and run Liberty Hill Farms for over 30 years. Although small sections of their extensive farmlands have flooded every year, Irene caused their farming business unprecedented damage totaling $545,000.[24] Fortunately, their home did not sustain any damage during the flooding. For personal and economic reasons, they state, "the land was their livelihood" and "it is not an option to move." They have not been able to make any preparations for another flood, as they aren't yet done cleaning up from the Irene flooding.

Beth and Bob feel very connected to the community of Rochester. They were very satisfied with how people came together and helped each other. They shared many stories of friends and volunteers helping others in Rochester to cope with the effects of Irene.

[24] Kennett, Beth and Bob Kennett. (2012, April 24). Personal Interview.

They noted, "[Rochester] is a community that [we] want to stay in." The flood had "reinforced community rather than destroyed it."

They did not receive any assistance from FEMA, as there was no damage to their home. The state doesn't have many programs that aid small businesses, and the programs that do exist have grants and loans that are capped so as to help as many businesses in the state as possible. The assistance they did receive was very limited, and the Kennetts were forced to take out a mortgage on their property to pay for the damage caused by Tropical Storm Irene.

Figure 9. Bob and Beth Kennet, Liberty Hill Farm, Rochester, VT. Photo by Liberty Hill Farm Inn.

VI. Analysis and Recurring Themes

A. Attachment to Current Residence

As we see an increase in storm frequency and intensity in the progression of climate change symptoms, repeatedly damaged areas, described in Chapter 3 of this report, will become more common. One way to avoid the increased cost—both financial and emotional—of repeated damage to residences is to relocate residents living in damaged or at-risk areas; however, the majority of the residents we talked to and received surveys from expressed an unwillingness to relocate from their current homes. The same pattern of attachment to current residence appears in conversations in the media.

Longevity in the community was correlated to this unwillingness to relocate. Few residents living in their homes or communities for a long time were willing to find a new home. Michelle Pingree believes that relocating is the right thing for her to do after her

property was damaged during Irene.[25] Harder, though, is convincing her in-laws, who have lived in their home longer than she has. “Mom and dad, they’re having a hard time letting go. They lived here for sixty years and raised four kids. It’s very hard for them to move on,” said Pingree.

Figure 10. Sign on Michelle Pingree’s in-laws home, April 5, 2012. Photo by Michelle Pingree.

While explaining her family’s history and connection to their home, Pingree showed pictures of their sugarhouse. She described it as a gathering place for her extended family. Just the day before Irene struck Plymouth, their family had gathered at the sugarhouse for a family reunion. The property was central to the Pingrees’ family traditions, and Pingree cited this as contributing to their resistance to move.

Figure 11. Pingree family reunion at Sugarhouse one day before Irene. Photo by Michelle Pingree.

[25] Pingree 2012.

Similar to the older Pingree generation, Betty and Bill Jarvi of Plymouth did not consider relocating even after their basement flooded during Irene causing $9,000 worth of damage.[26] Bill Jarvi has lived in Plymouth since his parents moved there in 1926, when he was two. Betty Jarvi summered with her family at the Echo Lake Inn since her childhood. The extent of their family history in the community was clearly a source of pride as Mr. Jarvi explained the story of his father selling a Model-T ford to buy their family's first farm. This deep sense of familiarity with the region could be a reason for their unwillingness to move.

Their satisfaction with FEMA's assistance and the fact that they don't live in a floodplain could be reasons that the Jarvis are not compelled to find a new home. FEMA responded quickly to their damage, insisting that they move out of their home for a few days to avoid mold inhalation. FEMA also paid for the removal of the mold in full. There is a sense of security provided by the comprehensive aid they received. The Jarvis also believe that these flood events happen so infrequently that the likelihood that another extreme weather event should occur in their lifetime is too low to merit relocation.

This pattern of resistance to relocation for longtime residents is greater than the Pingree and Jarvi families, as seen in the compiled survey and interview responses. Figure 12 shows the responses of 17 individuals to the question, "Are you willing to relocate?" The respondents are classified by the number of years they've lived in their current homes: 0-5 years, 5-20 years, or over 20 years. One hundred percent of respondents living in the community over 20 years reported unwillingness to relocate. Though longevity of residence appears to be correlated with resistance to relocate, we wanted to understand the motivations of residents to remain. Thus, we tried to decipher the reasons for our interviewees' attachments to their current residences through direct or indirect questions. The most common response we received was something along the lines of "because it's our home." From these responses we were reminded of the complexity of the endeavor to understand human sentiments. The sentiments towards home and community are held close by all residents. For many, it is as simple as the Kennetts said: "It is not an option to move."[27]

[26] Jarvi 2012.
[27] Kennett 2012.

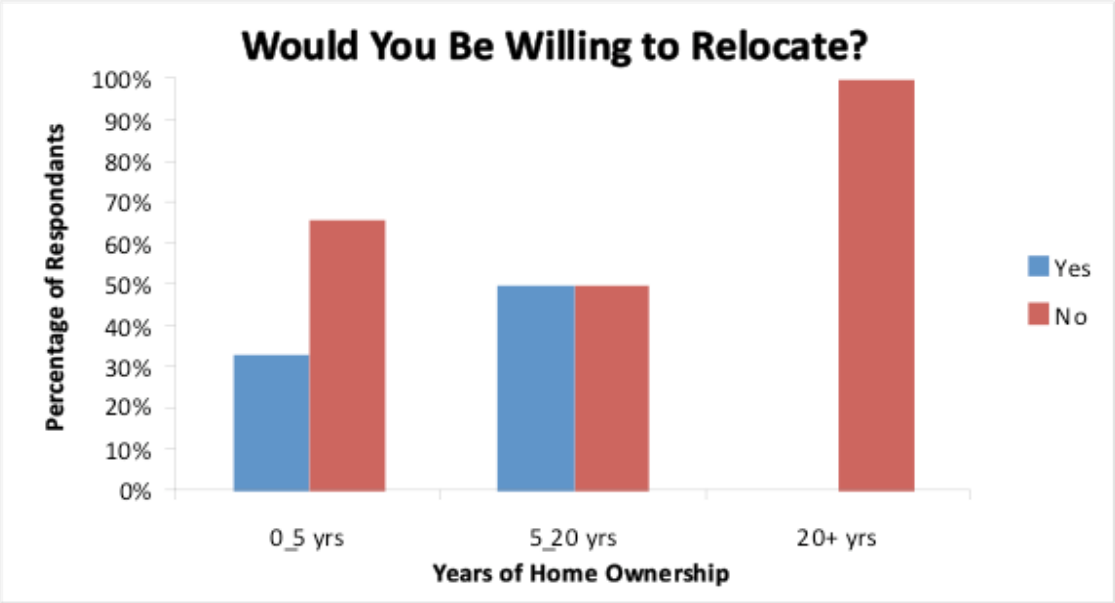

Figure 12. Willingness to relocate as a function of years of home ownership (N=17).

Similar sentiments were expressed in a recent interview series by Vermont Public Radio that spotlighted individuals and families who had lost their homes during Tropical Storm Irene. This attachment was particularly strong for residents who had raised a family in their home. For example, the Gervais family of Wardsboro, VT witnessed the complete destruction as their house as waters from Wardsboro Brook inundated the main floor of their raised ranch home.[28] Vera and her husband, Dennis Gervais, expressed the difficulty of both being empty nesters and living without the place they called home for 23 years: "Every once in awhile it just hits you; this is gone. That's gone. I don't have that anymore. We're not in our home. The kids are gone. Empty nest syndrome, but it's not that. It's everything. Empty house syndrome; we're on a bad vacation; will we get home soon?"[29]

[28] Cohen, Nancy Eve. "After Narrowly Surviving Irene, Wardsboro Family Waits for a Resolution." *Vermont Public Radio*. 2 Feb. 2012.
[29] Cohen 2 Feb. 2012.

Figure 13. Vera Gervais and her son Travis outside their home. Photo by Vermont Public Radio.

In addition to duration of home ownership, personal investment in the property played a key role in determining resident's attachment to their homes. One couple in Newfane described the extensive work they had put into their home of 8 years before it was washed away by Irene including remodeling the bathroom, redoing the floors, and building a river rock wall along the property.[30] The couple described the difficulty of witnessing their years of hard work go to waste; however, they admitted that although "what happened to our house is horrible, it's much easier than having to, I think, clean out a house you can't live in anymore and go back over to just salvage things."

For some, the issue of relocating is an economic one. In particular, those individuals with home businesses faced a greater cost of relocating. Lawrence Jeffries, owner of the Echo Lake Inn in Plymouth, lost a lot in the storm but believes the future cost of relocating is greater.[31] Caroline Meathers of Hancock also hosts a business in her home and faced great cost due to the storm.[32] If a buyout isn't provided, land in damaged or at-risk areas can be difficult to sell, making buying new property an insurmountable cost. Susan Mordecai of Plymouth's land was damaged beyond the point of continued residence but has yet to be offered a buyout by the government.[33] She said that she couldn't resell the land because "it's all holes and gullies. A lot of the property washed away." Even if she had been able to sell the land, the property value dropped by over $100,000. Mordecai was told she couldn't continue to live in her destroyed home so she

[30] Cohen, Nancy Eve. "Newfane Couple is Determined to Find New Home." *Vermont Public Radio*. 1 Feb. 2012.
[31] Jeffries 2012.
[32] Meather 2012.
[33] Mordecai 2012.

had no choice but to relocate. But for others with more moderate damage and the desire to relocate, the economic obstacle of selling their home could be a reason to remain.

Figure 14. Susan Mordecai's Property one day after Irene. Photo by Michelle Pingree.

B. Impact on Local Economy

Tropical Storm Irene damaged many homes and businesses within the study areas. Because FEMA assistance only applied to residential housing, Caroline Meather of Rochester and her husband had to take out loans through the Small Business Administration and VEDA in order to pay for the damages to their electronic design company caused by the flooding.[34] Betty and Bill Jarvi of Plymouth said that many of their neighbors rely on income from summer rentals to sustain themselves economically year round. Since sediment flowed heavily off the hills and into Echo Lake during the storm, the usually popular swimming area is contaminated and the lake has been deemed unsuitable for summer recreational use by the state.[35]

Lawrence Jeffries, the owner of the Echo Lake Inn in Plymouth who lost $13,000 of wine, $7,000 worth of refrigerated goods and equipment, and 2,400 square feet of storage place when his basement was flooded, notes that none of these costs were covered by flood insurance. Jeffries said "I don't have as many wines as I used to have, and I'm not buying many because it could happen again." The Inn had to be closed for 5

[34] Meather 2012.
[35] Jarvi 2012.

weeks following Irene during peak foliage season, resulting in heavy financial losses for Jeffries' business.[36]

Other tourism establishments in Plymouth, such as the Salt Ash Inn and the Farmbrook Motel, were also struck by Irene, compounding the impact to the local economy. Tourism is an important revenue source for many rural Vermont towns, and the five-town region is no exception.[37] The Kennett family of Liberty Hill Farm in Rochester faced damage that has cost them nearly $550,000. They are still working on repairing the damage and due to caps and limits on the different sources of assistance, it will be years before their farm can get back to full capacity. The Rochester economy will equally suffer because, as the Kennetts point out, "the land was [our] livelihood."[38]

Figure 15. Farmbrook Motel, Plymouth, VT, April 5, 2012.

This financial burden on individual homeowners and local economies and businesses was seen throughout Vermont, especially in cases where residents' businesses were located within their damaged homes.[39] Anne Coleman, of Wilmington, VT witnessed her art gallery floating over 2 miles downstream.[40] The gallery represented a $400,000 investment on her part and was an integral part of the town's cultural landscape. In the town of Wilmington alone, more than 100 local businesses were

[36] Jeffries 2012.
[37] Lynds 2012
[38] Kennet 2012.
[39] Kennet 2012. Meather 2012.
[40] Davis, Lindsey, and Anne Coleman. "Keep on Keeping On: Vermont Artist Helps Community Rebuild After Irene." *ABC News.* ABC. Wilmington, Vermont, 5 Sept. 2011.

impacted causing an estimated $8.5 million worth of damages.[41] Family-owned agricultural operations were particularly hard-hit with an estimated total of $10 million worth of losses due to Irene.[42] The recently appointed Secretary of Agriculture, Chuck Ross, reiterated these effects on small farms in a January interview, "When you consider the impact of Irene and compound some of the pressures farms are already under, we may lose a few. I think it's fair to say we're going to lose a few farms."[43]

As expressed by Caroline Meather of Rochester, FEMA assistance applies strictly to residential buildings.[44] In order to secure funding from other agencies and organizations such as the Small Business Administration or VEDA, flood insurance is required. In several interviews, residents expressed both the difficult process of applying for flood insurance as well as the variable costs, "I wish I had flood insurance but again, I couldn't afford it, I can't even afford health insurance."[45] These stories indicate that small business owners face both the burden of dealing with the psychological trauma of experiencing a disaster of Irene's magnitude as well as the financial burden of recovering and rebuilding their businesses.

C. High Social Capital

In our interviews and surveys, we consistently heard references to a high level of social capital in our study areas. Residents were very satisfied with the community response during and after the flood—rebuilding roads, bailing out basements and providing hot meals to isolated neighbors. These volunteered acts of togetherness inspired residents' pride in their neighbors and were conducted in a spirit that was described as distinctly Vermont.

We heard stories of selflessness and heroism and a collective sense of responsibility. For example, Michelle Pingree and her husband set up a canteen in the town office and served the whole town of Plymouth lunch daily in the week following

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[41] Lunderville, Neale. Irene Recovery Report. Irene Recovery Coordination Team and the Vermont League of Cities and Towns. January, 2012.
[42] Lunderville 2012.
[43] Lindholm, Jane. "Vermont Farmers Continue Recovery from Irene." *Vermont Public Radio.*18 Jan. 2012.
[44] Meather 2012
[45] Davis & Coleman 2011.

Irene.[46] Larry Lynds told the story of a community member who was rescued from her mobile home by her neighbor.[47]

Communities were also involved in the efforts to clean up, repair and rebuild. Caroline Meather shared how "the next day [after the flooding], six guys from Middlebury came by offering their help. The community has been fantastic."[48] Michelle Pingree described how rapidly the town responded in trying to give residents access to other towns with the construction of "Rocky Road" off Route 100. "They really hit the ground running," she said, making the road passable just a few days after the storm.[49] Beth Kennett recalls, "Everyone came together and started working again. They didn't wait for others to come and help. They came together, started cooking, cleaning...People came together to provide meals at the school, to organize barbeques and clean-ups. There were so many volunteer efforts."[50]

Figure 16. Temporary Rocky Road providing access out of Plymouth. Photo by Michelle Pingree.

Our interviewees spoke of the resilient attitude that many Vermonters held that inspired them to "get up and get the work done." This attitude galvanized state pride, which the Kennett family described in an anecdote in which "the Governor came to Rochester and said that he was talking to the Governor of New York who asked how he

[46] Pingree 2012.
[47] Lynds 2012.
[48] Meather 2012.
[49] Pingree 2012.
[50] Kennett 2012

had managed to get the roads and bridges and stuff up so fast. The Governor just said that it was Vermont. You just get up and do it."[51]

These accounts of high social capital and network of community support were echoed in countless stories of individual heroism in the local media. In one case, a Londonderry family was so humbled by the response of both friends and strangers in the aftermath of Irene that they decided to remain within the community rather than moving to Florida to be closer to their elderly parents. "We toyed with the idea of moving away and we've done a 180 on that. We're not going anywhere. This is where we belong," they said.[52] The family, who runs a window-cleaning business for second home owners in the area, described how strangers they had never met before, including clients of theirs who they only knew from washing their windows once or twice a year, drove up to assist in salvaging belongings from their ruined home.

Figure 17. Money Brook cleanup, Plymouth, VT. Photo by Michelle Pingree.

Both during Irene and in the following months, community members opened their homes to residents whose houses were either completely destroyed or severely damaged by the storm. The Gervais family of Wardsboro sought refuge in their neighbors' trailer as they witnessed the surging waters of Wardsboro Brook engulf their mobile home.[53]

[51] Kennets 2012.
[52] Cohen, Nancy Eve. "After Irene, Londonderry Family Counts Blessings". *Vermont Public Radio*. Feb 03, 2012.
[53] Cohen, Nancy Eve. "After Narrowly Surviving Irene, Wardsboro Family Waits for a Resolution." *Vermont Public Radio*. 2 Feb. 2012.

Tara Torcoletti and her boyfriend were able to rotate between staying with three strangers rent-free as they searched for a new house in the six months after Irene.[54] Across the state, Vermonters made their fellow citizens a priority. Irene was a transformative event in reasserting the collectivity and unity of Vermont towns and cities, as Rihanna Graham Frock put it, "A lot has changed. When you think back, the town really is so different than before Irene hit, the businesses have all come together to make sure they keep going and the community came together during the flood and we just sort of realized we're all here for each other. It brought us closer together."[55]

Figure 18. Governor Peter Shumlin visits Rochester 3 days after Irene: masslive.com.

D. Mixed Perspectives on Government Support

Based on our surveys and interviews, we noted that there were both positive and negative opinions on the role of FEMA and the state of Vermont in responding to the damage caused by Tropical Storm Irene. There were some residents who were satisfied with the FEMA response and not with the state response and conversely, others were satisfied with the assistance that the state provided but were frustrated with the claims filing process through FEMA.

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[54] Cohen, Nancy Eve. "Newfane Couple is Determined to Find New Home." *Vermont Public Radio*. 1 Feb. 2012.

[55] Mitch Wertlieb. "After Irene, Rochester Teen Says Life Slowly Returning to Normal." *Vermont Public Radio*. 30 Dec. 2011.

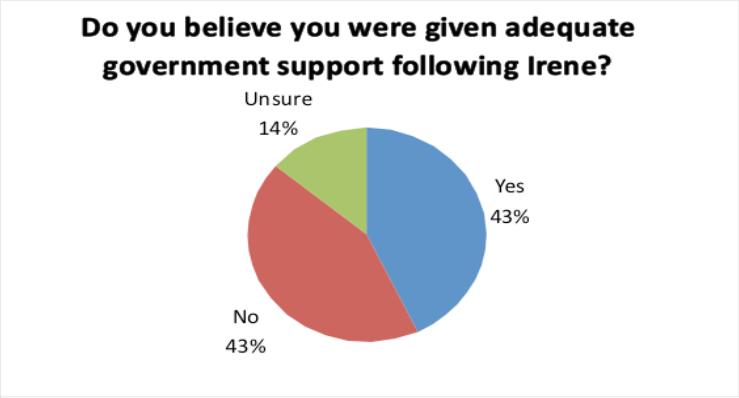

Figure 19. Resident perspectives on government support. (N=17).

Cathy Curtis, the town clerk in Hancock, had a good working relationship with FEMA. The town had to take out 3 loans to pay for washed out roads and bridges. FEMA was expected to reimburse 75% of that cost, the rest would be covered by the state and town, 15% and 10% respectively.[56] Curtis was appreciative of such assistance from the state and FEMA.

Michelle Pingree spoke of the tremendous support that the National Guard provided Plymouth with clean up and with food drops.[57] Susan Mordecai of Plymouth was happy with how rapidly FEMA sent her money immediately following Irene when her house was destroyed. She was also impressed with the sensitivity with which FEMA employees interacted with her about her loss. She said they had clearly been trained in the psychology of disaster victims and wished that the state had had similar training and expertise.[58]

Figure 20. National Guard members provide food to Rochester residents. Source: dvidshub.net.

[56] Curtis 2012.
[57] Pingree 2012.
[58] Mordecai 2012.

The importance of emotional support networks was illustrated in several residents' experiences. Mordecai and other interviewees described struggles with depression and coming to terms with both the financial and emotional losses caused by Irene. Michelle Pingree, for example, said, "I had Irene depression. I was dealing with everybody else's problems, then my in-laws, and then my own." [59] The ability to deal with this form of psychological trauma was something that the state lacked.

Many of the people with whom we talked were dissatisfied or confused with insurance. For example, Michelle Pingree said, "it's pretty much the owner's responsibility if you didn't have any insurance, which most of us around here didn't have because who thinks of flood insurance?"[60] Even some who did have flood insurance were dissatisfied with the assistance they received from the insurance program. For example several individuals received no financial assistance because their basements, not included in flood insurance coverage, were destroyed.[61] Lawrence Jeffries had purchased flood insurance for $300 but found that it didn't cover his most expensive items including $13,000 worth of wine, $7,000 worth of refrigeration and 2,400 square feet of storage space.[62]

FEMA aid does not extend to owners of second homes. Larry Lynds described how the town of Ludlow, near Plymouth, also sustained damage but as nearly 80% of homes are secondary residences they were unable to get much aid from FEMA.[63] Other residents did not qualify for aid despite experiencing extensive damage as they were located outside the designated floodplain. For example, Susan Mordecai did not qualify for a buyout (through FEMA Hazard Mitigation) because her home wasn't technically in a floodplain.[64] In reality, her home was damaged in 1973 and 2011, though the recent flood caused significantly more damage. Mordecai was eventually successful in receiving some aid from FEMA after she proved that her home had been damaged in 1973 as well.

[59] Pingree 2012.
[60] Pingree 2012.
[61] Meather 2012; Jarvi 2012; Jeffries 2012
[62] Jeffries 2012.
[63] Lynds 2012.
[64] Mordecai 2012.

Some residents were unhappy with the role of the state in the response. For example, Michelle Pingree said the state made her buy a 100-year flood culvert costing her $5,000 and the town didn't help pay for it at all.[65] Also, Susan Mordecai said "Governor Shumlin asked me who I was. I said I'm a state employee, I'm a teacher. And so we're in my backyard and I say, 'Who cleans this up?' and he said 'You do.' And I said 'I'm not twenty, I can't.'"[66]

Media coverage of the process of financial reimbursement through FEMA highlighted residents' frustrations with the Hazard Mitigation and flood insurance claims filing process. Several families found themselves paying mortgages on destroyed homes as they waited for a buyout from FEMA. In the case of the Graham-Frock family of Rochester, the process is ongoing.[67] Back in November, the family applied through FEMA for Hazard Mitigation, which pays 75% of the assessed value of residences located within floodplains in order to convert those properties to public green space.[68] As of March, the family had yet to receive a single dollar through the program and was informed it would likely be another eight months before they were reimbursed by FEMA. As Beth Graham-Frock put it, "This is something we've been hearing from a lot of people now that the checks are slow in coming, that there's a lot of frustration on that level."[69] Furthermore, the slow bureaucratic process has forced many residents to delay future plans. In the case of the Graham-Frock family, that means postponing college for their daughter Rihanna.

Residents found the claims filing process both difficult to navigate, and frustrating. Peg Elmer, an assistant professor for land use planning and policy at Vermont Law School described how she had to aggressively advocate for herself throughout the claims filing process with FEMA, since the first offer they made her was missing

[65] Pingree 2012.
[66] Mordecai 2012.
[67] Wertlieb, Mitch, Jon Graham, and Beth Frock. "Rochester Couple Works to Resolve Mortgage Issues on Destroyed Home." *VPR News*. Vermont Public Radio. Colchester, Vermont, 24 Oct. 2011.
[68] Lindholm, Jane. "Navigating Legal Territory After Irene." *Vermont Public Radio*. 20 Oct. 2011
[69] Wertlieb, Mitch. "Months After Irene, Rochester Family Still Waits for Resolution." *Vermont Public Radio*. 10 Jan. 2012.

coverage of several important items.[70] Only after she "pushed" them to cover more items, she said, did they pay her 50% more.

Our media analysis didn't delve specifically into the lack of psychological counseling and support on the state government level; however, the need for such a resource became apparent in reading several interviews. For example, it wasn't until two months after Irene that Beth Graham-Frock felt she could begin to process the experience, "I said to my mom today this is the first day I feel human. This is the first time I feel like I'm not walking around in a fog."[71] For many, although the financial losses were tough, processing the emotional experience was even more challenging and several residents described their struggle with "Irene depression".[72] Considered as a whole, these stories indicate a strong need for support both during the reimbursement and claims filing process, as well as resources for victims to deal with the psychological trauma caused by the storm.

Figure 21. Beth and John Graham Frock, Rochester, VT: Vermont Public Radio.

[70] Lindholm, Jane, and Ric Cengari. "Displaced by Irene: Issues Faced by Displaced Vermonters." *Vermont Public Radio*. Feb 2, 2012.
[71] Wertlieb, Mitch. "Rochester Couple Works to Resolve Mortgage Issues on Destroyed Home." *Vermont Public Radio*. 24 Oct. 2011.
[72] Pingree 2012.

E. Absence of Climate Change in Dialogue

In contrast to the frequency with which we heard about the strong community response and opinions about governmental support is the absence of climate change in dialogue, as a topic that wasn't brought up freely by our interviewees. It wasn't until we raised the subject in conversation that we heard individuals' views. We did so by asking questions such as "What do you believe caused the flooding?" or, more pointedly, "Are community members talking about increased storm frequency and its connection with climate change?"

Not all our interviewees rejected climate change. Once the subject was brought up, we saw a variety of responses. Some people were certain that Irene was a manifestation of the type of storms and precipitation amounts we can expect from climate change. Bill Jarvi, an eighty-eight year old retiree of Plymouth, for instance, believed that climate change was upon us and proceeded to explain how warmer air is responsible for higher precipitation levels. Bill's wife, Betty, however was still skeptical of anthropogenic-induced climate change, as were several other interviewees like the Poiriers and Eric LaPorte.

Some people believed in climate change but were unsure or unwilling to speak for the community as a whole. Cathy Curtis, town clerk of Hancock, was cognizant of "weather changing all over the world," but when asked if the community believed the same, she said she didn't want to speak for the rest because she didn't know.[73] Climate change, it seems, isn't a topic frequently discussed in the town office. Similarly, the Jarvis and the Poiriers expressed their opinions on climate change but couldn't tell us what their neighbors' beliefs were.

From our survey respondents, nine people responded to the question, "Do you believe climate change is the cause of Tropical Storm Irene?" Five respondents believed in the connection between Irene and climate change. Three respondents said that Irene was definitely not attributable to climate change and one respondent was conflicted. The low response to this question (nine out of 20 individuals responded) demonstrates an unwillingness to engage in this conversation.

[73] Curtis 2012.

Climate change is not at the forefront of residents' minds. This could be affecting residents' perception of future risk. Without the greater emphasis on connection between increased storms and climate change, Irene seems an anomaly unlikely to recur; however, in the mind of a resident cognizant of the increased odds, the risk of repeat damage looms.

F. Absence of Floodplain Awareness

In our surveys and interviews, we found that some residents were unaware of whether or not their home or business was located within the floodplain. Cathy Curtis spoke of her neighbor's home in Hancock, which was severely damaged. Her neighbors had not considered their home in the floodplain but now they were certain that they were indeed in the floodplain and in danger of repeated damage from floods in the future.[74] Caroline Meather and her husband said that because they were not in the designated floodplain they were especially unprepared. They had never had problems with flooding before and had even escaped the flood of 1927 with no damage.[75] Betty and Bill Jarvi live on a hill near a creek between Plymouth and Ludlow, not within a floodplain. Irene flooded their basement regardless of their floodplain designation, which took them by surprise.[76]

Figure 22. Trailer home destroyed by Irene off Rt 100A, Plymouth, VT.

In the media, it became evident that information regarding floodplain zones was not readily available to homeowners and often that information had to be sought out by

[74] Curtis 2012.
[75] Meather 2012.
[76] Jarvi 2012.

the homeowners themselves. Additionally, there were instances in which homes were outside the designated floodplain zone, yet had experienced previous flooding. For example, when Peg Elmer first purchased her home in South Royalton, she discovered from the previous residents that the home experienced damages during the 1927 flood as well as several smaller flooding events.[77] As a result, she opted to purchase flood insurance at a higher premium despite the fact that her home was outside of the floodplain.

VII. Conclusion and Recommendations.

As a result of our personal interviews and dialogues with residents, policy makers, business owners, scientists and Vermont State employees, we have been able to acquire a broad spectrum of opinions and stories about Tropical Storm Irene and the recovery process. We have thus developed a number of recommendations. With this in mind, we also acknowledge our limitations. We are not necessarily trying to inform new specific policy implementations or rewrite legislation. Rather, we are attempting to convey the understanding we have gained to encourage better communication and, in turn, better policy. We have had the unique opportunity to approach this complex and emotional subject from a "30,000 foot view," and we hope to share this with decision-making parties.

First and foremost, the State should create and utilize a training program for government officials in the field of disaster psychology. Affected residents survived a very traumatic experience, and there appears to be a disconnect between government policy and response and the psychologically vulnerable state of victims. A number of residents expressed dissatisfaction with government support, and one resident even entered what she referred to as an "Irene Depression." Currently, Stand Strong Again Vermont offers FEMA-funded support services for Irene victims. This needs to be well-advertised and incorporated into standard government procedure. With improved training in disaster psychology, government officials could communicate with residents more effectively and sensitively.

[77] Lindholm, Jane, and Ric Cengari. "Displaced by Irene: Issues Faced by Displaced Vermonters." *Vermont Public Radio*. Feb 2, 2012.

On a more technical level, we would encourage a quicker and more thorough follow up after the initials claims filing process. Many residents we spoke with are still waiting for financial aid from FEMA or the State. There remains a lack of clarity regarding available funding, and residents are waiting in limbo. Improved communication between affected residents and funding agents would allow for better planning and better informed financial decisions by the residents.

Floodplain maps *must* be up to date and easily accessible by all residents. Floodplain designation significantly affects financial, political and social decisions. With greater communication on this issue, both residents and policy makers could make better-informed and more responsible decisions. Once these floodplain regions are updated, it would be prudent for the State of Vermont to, at the very least, strongly discourage inhabitation of floodplains. Most residents harbor strong emotional attachments to their homes. Combining this with financial instability, moving is simply not an option for most floodplain residents. If the State of Vermont wants to discourage floodplain inhabitation, a top-down approach will be required. Avoiding floodplain development would significantly reduce personal injuries and property damage, and the State will need to take the reins to make this consideration a reality.

On a related note, lack of climate change dialogue in our personal interviews suggests that, while Irene-caliber storms will occur with greater frequency due to changing temperatures, residents remain unaware of this reality. To ensure a comprehensive understanding of the relevant science, it would be beneficial to ensure that accurate climate change lessons and dialogues are incorporated into all levels of public discourse. In our study we also identified areas that should continue to be explored. We looked into why people wanted to stay; future projects can begin to look into why people moved there in the first place. Encouraging Vermonters to live in floodplains should end immediately. Even more important, we need to start looking into ways to build somewhere else. Buyouts and other programs work at one level; there are other levels, however, which have not received nearly enough attention. From our research we gathered that some people would move if they had the resources, but others are very attached to their homes, towns, and community that they have lived in for years. Would more knowledge about the changing climate make a difference? Would more

information about the risks make people more likely to move? Or are people simply too attached to move? Further research into to these questions will help guide the next steps in rebuilding and preparing for future floods and/or other disasters. More research should also be done to determine whether subsidized flood insurance and other unknown incentives are causing people to stay. We do not want these residents to constantly face damage and to continue to rebuild at high emotional and economic cost.

One of our most heavily supported observations was the overwhelming satisfaction with the community and the local government's support. Identifying problematic areas is just as important as identifying areas of strength. We believe social capital is one of the greatest resources we have in the state and this social capital is and can continue to be a great asset to Vermonters. Throughout the course of our study our project evolved, and the original focus shifted from a quantitative endeavor of collecting as much data as possible to a more reflective study of the stories of the residents of Plymouth, Hancock, and Rochester. We used three main sources of data: surveys, personal interviews, and media stories to complete our analysis and produce tangible recommendations for policy makers. We see our project as part of a group of projects that hope to collect the stories of those that lived through tropical storm Irene. Increased communication and collaboration between institutions such as the Vermont Folklife Center and various writers, newspapers and town organizers would be of great help in fulfilling this mission. These stories are essential to the process of recovery because they provide key insights into the resident's experience and they serve as a way to unburden some of the heavy psychological distress that the flood caused these residents. Our work is one step in a much more critical process: to keep these stories and opinions alive and to value them for the great resource that they are. Each story is significant, each story is an important piece of the puzzle, and each story provides a clue into what surviving through an event of this magnitude means. Our hope is that these recommendations will help shape more effective policy; policy that speaks to the people's needs.

VIII. Bibliography

Baker, Aylie. “Interviewing in the Wake of Hurricane Irene.” *Vermont Folk Life Center.* Middlebury, Vermont, 2011.

Cohen, Nancy Eve. “After Irene, Londonderry Family Counts Blessings”. *Vermont Public Radio*. Feb 03, 212.

Cohen, Nancy Eve. “After Narrowly Surviving Irene, Wardsboro Family Waits for a Resolution.” *Vermont Public Radio.* 2 Feb. 2012.

Cohen, Nancy Eve. “Newfane Couple is Determined to Find New Home.” *Vermont Public Radio*. Feb 01, 2012.

Davis, Lindsey, and Anne Coleman. “Keep on Keeping On: Vermont Artist Helps Community Rebuild After Irene.” *ABC News.* ABC. Wilmington, Vermont, 5 Sept. 2011.

Federal Emergency Management Agency. “Help After a Disaster: Applicant’s Guide to the Individuals & Households Program.” *FEMA 545.* The Federal Emergency Management Agency. July 2008.

Helsloot, I. and Ruitenberg, A. (2004), “Citizen Response to Disasters: a Survey of Literature and Some Practical Implications.” *Journal of Contingencies and Crisis Management*, 12: 98– 111. doi: 10.1111/j.0966-0879.2004.00440.x.

Jarvi, Betty and Bill Jarvi. (2012, April 5). Personal Interview.

Jeffries, Lawrence. (2012, April 5). Personal Interview.

Kennett, Beth and Bob Kennett. (2012, April 24). Personal Interview.

Lindholm, Jane, John Campbell, and Samantha Fields. “Navigating Legal Territory After Irene.” *Vermont Edition.* Vermont Public Radio. Colchester, Vermont, 20 Oct. 2011.

Lindholm, Jane, and Ric Cengari. “Displaced by Irene: Issues Faced by Displaced Vermonters.” *Vermont Public Radio*. Feb 2, 2012.

Lindholm, Jane. “Vermont Farmers Continue Recovery from Irene.” *Vermont Public Radio*. 18 Jan. 2012.

Lunderville, Neale. Irene Recovery Report. Irene Recovery Coordination Team and the Vermont League of Cities and Towns. January, 2012.

Lynds, Larry. (2012, April). Personal Interview.

Meather, Caroline. (2012, April 12). Personal Interview.

Mordecai, Susan. (2012, April 15). Personal Interview.

Pingree, Michelle. (2012, April 5). Personal Interview.

Poirier, Sue and Al Poirier. 17 April 2012. Personal Interview.

Sims, John H., and Duane D. Baumann. "Educational Programs and Human Response to Natural Hazards." *Environment and Behavior* 15:165. 1983.

Smart Growth Vermont. "Historic Settlement Patterns." http://www.smartgrowthvermont.org/learn/patterns/, visited May 1, 2012.

Starting Over Strong Vermont. "News and Press Releases." http://startingoverstrongvermont.org/?page_id=22, visited May 2, 2012.

US Census Bureau. "Profile of General Population and Housing Characteristics: 2010. Hancock town, Addison County, Vermont." http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_10_DP_DPDP1&prodType=table, visited May 12, 2012.

US Census Bureau. "Profile of General Population and Housing Characteristics: 2010. Plymouth town, Windsor County, Vermont." http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_10_DP_DPDP1&prodType=table, visited May 12, 2012.

US Census Bureau. "Profile of General Population and Housing Characteristics: 2010. Rochester town, Windsor County, Vermont." http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_10_DP_DPDP1&prodType=table, visited May 12, 2012.

US Census Bureau. "Profile of General Population and Housing Characteristics: 2010, Vermont." http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_10_DP_DPDP1&prodType=table, visited May 12, 2012.

US Census Bureau. "Selected Economic Characteristic: 2006-2010. Hancock town, Addison County, Vermont." http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_5YR_DP03&prodType=table, visited May 12, 2012.

US Census Bureau. "Selected Economic Characteristic: 2006-2010. Plymouth town, Windsor County, Vermont."

http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_5YR_DP03&prodType=table, visited May 12, 2012.

US Census Bureau. “Selected Economic Characteristic: 2006-2010. Rochester town, Windsor County, Vermont.” http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_5YR_DP03&prodType=table, visited May 12, 2012.

US Census Bureau. “Selected Economic Characteristic: 2006-2010, Vermont.” http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_5YR_DP03&prodType=table, visited May 12, 2012.

Vermont Agency of Natural Resources. “Tropical Storm Irene: By the Numbers.” http://www.anr.state.vt.us/anr/climatechange/irenebythenumbers.html, visited May 2, 2012.

Waterstone, Marvin. “Hazard Mitigation Behavior of Urban Floodplain Residents.” *Institute of Behavioral Science, Boulder Colorado*. 1978.

Wertlieb, Mitch, Rhianna Graham-Frock, and Beth Frock. "After Irene, Rochester Teen Says Life Slowly Returning to Normal." *VPR News*. Vermont Public Radio. Colchester, Vermont, 30 Dec. 2011.

Wertlieb, Mitch, Jon Graham, and Beth Frock. "Months After Irene, Rochester Family Still Waits for Resolution." *VPR News*. Vermont Public Radio. Colchester, Vermont, 10 Jan 2012.

Wertlieb, Mitch, Jon Graham, and Beth Frock. “Rochester Couple Works to Resolve Mortgage Issues on Destroyed Home.” *VPR News*. Vermont Public Radio. Colchester, Vermont, 24 Oct. 2011.

Wertlieb, Mitch, Jon Graham, and Beth Frock. “Rochester Family Prepares for Post-Irene Holidays.” *VPR News*. Vermont Public Radio. Colchester, Vermont, 21 Nov. 2011.

Wertlieb, Mitch, Jon Graham, and Beth Frock. "Recovery Continues for Rochester Family." *VPR News*. Vermont Public Radio. Colchester, Vermont, 10 Mar. 2012.

Appendix A: Stories from the Media

Graham Frock Family of Rochester, VT: Series of 5 Interviews, VPR 10/24/11 - 03/12/12

VPR has been periodically interviewing the Graham-Frock family since the October following Tropical Storm Irene. Beth Frock, a clothing store owner, and Jon Graham an acquisitions editor for a publishing house live in Rochester with their 12-year-old daughter Chloe, and their 16-year-old daughter Rhianna. Last August, the family lost their house of 15-years to Tropical Storm Irene. The family is currently living in the home once owned by Jon Graham's mother who passed away in late 2010 and is working to both rebuild their lives and deal with the mortgage on their destroyed home. Among the primary challenges facing the family are:

1. Issues with insurance on their home – although they were able to receive the maximum amount from FEMA Recovery, they were not able to receive any money from homeowners insurance even though they were covered. The majority of FEMA funds were spent replacing clothing and basic necessities and the remaining funds will likely go towards cleaning up their destroyed property.

2. Navigating FEMA's Hazard Mitigation process – this program allows the town to buy out property and convert it to green space. If approved for Hazard Mitigation they are hoping to work out a deal with Merchant's bank regarding the mortgage on their old home. The couple expressed conflicting thoughts on the negotiation process with Merchant's Bank, as Beth put it "the bank is nothing, zero, that's what they're offering us." Jon, however, noted that "the bank is hoping the hazard mitigation will go through and they'll be able to get a good chunk of what we owe them from the mortgage out of that, and they don't want to consider any other options until this one has come through." As of March, FEMA had extended the deadline another month meaning the family was not expected to hear back about whether or not they were approved for another 8 months, complicating the process of brokering a deal with the local bank.

3. Dealing with the psychological and emotional trauma of disaster – Beth described how the loss of their home has been tough on her as well as her two daughters. Back in October, nearly two months after Irene, Beth admitted "I said to my mom today this is the first day I feel human, this is the first time I feel like I'm not walking around in a fog. And the kids, they were upstairs having this kind of fight they used to always have the other night, and I was just so happy they're returning to this sibling thing they used to have. I had to laugh about it at the time."

In the end, the family admitted that Irene has taught them some important lessons: "You can plan all you like but something like this can just come along and sweep it away. What matters is gratitude. You can look at things and say why me? And feel sorry about yourselves or you can look at things a just try to move on."

Displaced by Irene: Issues Faced by Displaced Vermonters, VPR 02/02/12

This interview highlighted the difficulties faced by Vermonters who have been displaced by Tropical Storm Irene. At the time of the interview in February ½ of the 1,400 homeowners devastated by the storm have not been able to return to their homes. The interviewer, Nancy Cohen listed several questions Vermont homeowners are facing:

- Will they have enough money to purchase a new home?
- Are they going to be able to get a mortgage on a new home when they're still paying their old one?
- How much money will they receive from the federal government?
- How much money do they owe to the bank on an old mortgage or home equity loan?
- When will they see FEMA Hazard Mitigation money?

Based on the interviewers observations it's more difficult for families whose homes were damaged to the point where they are unlivable yet still standing with furniture and ruined belongings in them, as it's as if they are living next to an archaeological ruin. She went on to describe the anxiety and unease associated with families who feel like they're living temporarily and don't know how long they are going to be living in an apartment or trailer that isn't their own home.

This interview also brought up differences in generation and education as it relates to recognizing the role of climate change in future disasters. In speaking with Peg Elmer, an assistant professor for land use planning and policy at Vermont Law School who owned a home in South Royalton that was damaged, she said she purchased flood insurance despite not being located in a flood plain citing the fact that "rivers are taking back their geologic river corridor" and that prior to purchasing the house she had asked the previous owners about their flood experience. Because she had flood insurance, she had the option to raise the house up, which minimized the damage from reaching the upper floors. Unfortunately, the designated floodplain maps are often outdated and as we saw through other media stories and personal interviews, many homes outside the floodplain received devastating damage. Additionally, Peg discussed how she had to advocate for herself when filing her insurance claim with FEMA saying that the first offer they made her was missing coverage of several important items and only after she pushed them to cover more items did they offered to pay her 50% more in the second offer. At the end of the interview, Peg voiced her opinions on rebuilding post-Irene: "In the work I do and looking at climate change and looking at increased frequency and intensity of storms, I think we need to be redesigning for the future."

Displaced by Irene: Wardsboro Family Waits for Resolution, VPR 02/02/12

The Gervais family of Wardsboro lived in their raised ranch home for 23 years located above a swimming hole along Wardsboro Brook. On the morning of the first day of Irene, their youngest son was about to leave for his first day of college. Initially, the family thought the rain would only last for a few hours. However by mid-morning the

family had to evacuate and wait out the rains in their neighbor's trailer along with 4 other neighbors, Tyler their youngest son recalled "By that time we couldn't get out of the driveway. We were stuck. And so we had to wait it out at our neighbor's trailer with water all around us. We had to watch everything float by, it was pretty awful." Rescue crews attempted to evacuate the trailer however at that point, the water was too high for the crews to reach them. Vera Gervais, the mother even phoned her eldest son, Travis at UVM to say she loved him as well as her niece to ask her to take care of her elderly mother should the family not survive the storm. Finally, around 6:30 pm rescue workers were able to ferry them out of the trailer to safety.

The house was completely destroyed by the flood, however neighbors and friends helped the family salvage clothes and furniture. Currently, the parents are empty nesters and are having difficulties both adjusting to living without their kids as well as without the place they called home for 23 years. Vera, the mother described the feeling: "Every once in a while it just hits you, this is gone. That's gone. I don't have that anymore. I sometimes just scream. When I come home at night and it's just pitch black that's hard. Because there was always light, the light left on for me to come home. And there's absolutely nothing here anymore. It's just black at night."

The town of Wardsboro has applied for a FEMA Hazard Mitigation Grant that would pay to knock down the Gervais' house and cap the septic, paying the family 75% of the property's assessed value before the flood. But the family has to subtract the $30,000 they already received from FEMA and the $77,000 they got from flood insurance. The community response has been overwhelming with the Stratton Foundation paying the family 25% of the value of their old home. The family is hoping to be settled in a new place by next summer.

Displaced by Irene: Londonderry Family Counts Blessings, VPR 02/0312

Jen and Dave Morris along with their four children have gone from living in a 4-bedroom 1,700 square-foot home in Londonderry to a one-bedroom apartment in the home of a friend after their home was destroyed by Tropical Storm Irene. Jen described how within 20 minutes after it had flooded their neighbors yard, water was rushing into her house. Luckily Dave was able to move the family's cars, and grab their computer, checkbook, and insurance policies before evacuating to South Londonderry. The local Fire Department required all Londonderry residents evacuate to South Londonderry since propane tanks were coming down the river and they feared that if they hit the bridge they would explode and endanger residents.

In the aftermath of Irene, Jen and Dave have been grateful for the incredible community-based response. Strangers they had never met before, including clients of theirs who they only knew from washing their windows once a year came up with their families to help salvage belongings. Jen described the experience as "humbling." Prior to Irene, the couple considered moving to Florida to be near their elderly parents but now, because of the support from friends and strangers, they've changed their mind and decided to remain in the Londonderry area. As Dave put it, "We toyed with the idea of

moving away and we've done a 180 on that. We're not going anywhere. This is where we belong."

Displaced by Irene: Newfane Couple is Determined to Find a New Home, VPR 02/01/12

Tara Torcoletti a 42-year old veterinarian and her boyfriend Brandon Holda a 34-year old social worker, witnessed Irene wash away their 2-bedroom ranch. All that the storm left on the property was an oil tank. Tara admits that losing her home completely is actually better than being left with a house that's destroyed as she's been spared the hardship of trying to salvage ruined belongings, "What happened to our house is horrible, but it's much easier than having to, I think clean out a house you can't live in anymore and go back over just to salvage things." She wishes however, that she'd had the chance to collect some sentimental items such as photographs and gifts from her stepfather and others who've passed away.

Financially, it's been a difficult loss. The couple owned the house for 8 years and put a lot of work into it between redoing the floors, bathroom, installing a new woodstove, windows, and a roof, and building an inside wall of river rocks. Although they have received $30,000 from FEMA the bank wants that money to pay off a home equity loan. The couple is hoping to save up to purchase a mortgage on a new home but at the time of the interview they had been rotating between staying at 3 different homes rent-free.

Navigating Legal Territory After Irene VPR, 03/10/12

In this interview with Senate President Pro Tempore John Campbell, some of the complicated legal issues that have arisen post-Irene are discussed. He addresses several topics such as mortgages on homes that were destroyed and issues of property rights. Some key points included:

1. Over 700 Vermont homes were either destroyed or significantly damaged by Tropical Storm Irene.
2. Due to the complexity and specificity of some of these housing issues the state will likely have to handle these situations on a case by case or town by town basis. For example, Brett Morrison from Jamaica, Vermont lost both his home and most of his property when the Ball Mountain Brook overflowed during Irene. The town has built a temporary road through his property that has been used to give mountain residents access to the downtown. He is currently still paying his mortgage and can't move until the town determines whether the road is temporary or permanent and what they want to do with his property.
3. The state is putting the onus on individuals to seek compensation for damages through FEMA's Disaster Mitigation program - if you had a house or property that sustained over 50% damage and your town will sponsor your application, FEMA will

pay 75% of the assessed value of the home. That land then has to become green space for perpetuity.

4. The majority of land damaged by the flood is likely not going to built upon and if residents wish to rebuild it is likely that towns will push for owners to purchase flood insurance which in some cases can be extremely costly.

Interview with Anne Coleman of Wilmington, VT - ABC News

On the day Tropical Storm Irene, hit, Anne Coleman witnessed her Art Gallery wash away over 2 miles downstream. The gallery was a $400,000 investment and a life-long dream for the Wilmington native. However, rather than focusing on her personal loss, she's chosen to devote her efforts to help friends, neighbors, and even strangers salvage belongings and get back on their feet post-Irene. Anne did however express her concerns over her lack of insurance coverage for the gallery: "I wish I had flood insurance, but again, I couldn't afford it, I can't even afford health insurance. I used all my savings to do this!"

5. Climate Change Adaptation in Vermont: With a Focus on Transportation and Housing

Rachel Callender, Supriti Jaya Ghosh, Harlem Siu Marino Saavedra, Rhiya Trivedi

I. Introduction: A Call to Action in a Post-Irene Environment

Tropical Storm Irene, A Wake Up Call

On August 28, 2011, Tropical Storm Irene hit Vermont. The strength, nature, and consequences of Irene were unparalleled in recent history—only tales of the 1927 Flood, which few current Vermonters lived through, were comparable.[1] As mentioned in previous sections, over 500 miles of state highway and around 200 bridges were damaged, and 34 bridges were fully closed down. In the wake of Irene, thirteen communities were left isolated as all roads to and from the towns were impassible. The Vermont Agency of Transportation acted quickly and established three Incident Command Centers across the state to address and repair damage in over 200 Vermont towns. With support from federal monies and transportation agencies of neighboring states, most roads and the entire state highway system were open by the end of December 2011.[2] Despite this quick turnaround, it was clear that aspects of the state's transportation infrastructure could be more resilient.

Not only bridges were destroyed leaving people disconnected from others for the span of days, but people were left with no homes to guard themselves from the fury of nature. Out of 4,954 property inspections documented by FEMA, they found that ~1,500 residences had been significantly damaged. Out of these residences, 433 were mobile homes, which housed mostly low-income families who could not afford to pay for alternatives such as hotels or to rebuild their homes. Moreover, at least 1400 households were temporarily or permanently displaced.[3] It is for all these reasons and the people who

[1] Clifford, D.R. and Clifford, N.R., 2007, The Troubled Roar of the Waters Vermont in Flood and Recovery, 1927-1931: University of New Hampshire Press, Durham, 258 p.
[2] Transportation Recovery. *I am Vermont Strong.* Vermont State Government. 2012. http://vtstrong.vermont.gov/Home/RoadRecovery.aspx.
[3] See: http://www.anr.state.vt.us/anr/climatechange/irenebythenumbers.html

suffer these losses that housing adaptation needs to play a significant role in the discussion about adaptation after Tropical Storm Irene in Vermont.

After Tropical Storm Irene hit, concerns arose about the state's vulnerability and resilience to such natural events, especially in light of predicted climate changes. As a response to these concerns, our working group has recognized the necessity to identify and address Vermont's vulnerabilities and the risks associated with a changing climate through sound management policies. In order to do so we must also acknowledge the different characteristics of Vermont which make it more vulnerable or resilient to the consequences of climate change.

The aim of our research is to develop recommendations for advancing Vermont's climate change vulnerability assessment and adaptation strategy, with a particular focus on transportation and housing policy. The connection between climate change and its consequences for infrastructure is a very new discussion in Vermont.[4] We identified transportation as a focus for our group because we would like to provide research that will be directly applicable and beneficial to our community partners, the Vermont Agency of Transportation, the Agency of Natural Resources Climate Change Team, and the Vermont Natural Resources Council. The Vermont Agency of Transportation has requested that we particularly look into risk assessment. We chose our other focus on housing policy because we were moved by the documentary, *Strength of the Storm*, which presents how Tropical Storm Irene impacted mobile home communities in Vermont and how these communities were resilient in the face of limited external support.[5] In order to achieve our goal we conducted an in-depth-study of other states' experiences with shaping policy to adequately address climate change effects as well as Vermont's efforts and potential to address climate change adaptation.

History of Flooding in Vermont

Within the last 100 years, Vermont has experienced many cases of devastating floods. In each case, these flood events have shown the necessity to adapt to nature's forces and dynamics. After the Great Flood of 1927, in which 84 people died, ninety thousand people were left homeless and millions of dollars worth of property was

[4] Campoli, G., Mackay, N., and Minter, S., 2012. Personal Communication.
[5] Koier, Rob. *Strength of the Storm.* Vermont Worker's Center. 2012.

destroyed, the only aim was to return to status quo as soon as possible.[6] After Tropical Storm Irene, the status quo approach revealed vulnerabilities in Vermont's recovery process and therefore the necessity for a forward-looking reconstruction approach was realized. The state of Vermont now looks to take climate change into consideration, namely the increasing intensity and frequency of natural disasters.[7]

Vermont strives to be a leader in climate change mitigation and adaptation, and although most of the current plans are related to greenhouse gas reductions,[8] the recognition of climate change as a serious issue to be addressed is significant for Vermont's success in this field in the future. Climate change adaptation and mitigation are two different subjects and must first be defined. Mitigation is the attempt to reduce or limit climate change primarily through minimization of greenhouse gas emissions. Adaptation is the concept that regardless of all mitigation efforts, the climate will continue to change in the near future and therefore society will need to adapt to predicted changes.

History of Climate Change Action in Vermont

The first step for Vermont addressing climate change was the adoption of two regional documents related to climate change mitigation and adaptation. They are the New England Governors/Eastern Canadian Premiers Climate Change Action Plan (2001) and Resolution 33-3 (2009). In the action plan, climate change adaptation is defined as "understanding regional climate changes and their impacts on our man-made infrastructure and our natural resources, including surface and ground water, forests and natural wildlife." Action Item 7 in this plan has to do with reduction of and adaptation to negative social, economic, or environmental impacts of climate change on biological or ecological systems.[9] Resolution 33-3 was a commitment to continuing the climate change

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[6] See: http://www.erh.noaa.gov/btv/events/27flood.shtml

[7] See: http://www.anr.state.vt.us/anr/climatechange/Adaptation.html

[8] Appendix 2: Plenary Group Recommendations & Appendices to the Governor's Commission on Climate Change, Final Report. 2007. Governor's Commission on Climate Change.

[9] New England Governors & Eastern Canadian Premiers, *Climate Change Action Plan.* 2001. The Committee on the Environment and the Northeast International Committee on Energy of the Conference of New England Governors and Eastern Canadian Premiers.

research and leadership in the region of the original NEGECP Climate Change Action Plan of 2001.[10]

The next major step for Vermont was the formation of the Governor's Commission on Climate Change (GCCC). The GCCC was formed on December 5, 2005 with Executive Order #07-05 by Governor Douglas.[11] The Commission consisted of six individuals, but a plenary group was formed under the commission consisting of 31 members/key stakeholders regarding the issue. What is significant about the GCCC and the associated plenary group is that they understood the ecological impacts of climate change, but did not necessarily consider the consequences to society and infrastructure. The GCCC set greenhouse gas (GHG) reductions as their primary goal. In the transportation sphere, this primarily translated to improved fuel efficiency, reduced carbon intensity of fuels, and reduced activity rates. Most related to this project, the plenary group made one suggestion related to climate change adaptation. The suggestion was that the state of Vermont should implement a Climate Change Adaptation Plan that specifically identifies the impacts of climate change that affect the state and creates a plan for addressing the impacts identified.[12]

Most recently, with Executive Order #05-11, Governor Shumlin created the Governor's Climate Cabinet. What is significant about this executive order is that it recognizes that the impact of GHG reductions is limited, and that climate will continue to change at this point regardless of reductions.[13] The goal of this cabinet is to be an interagency body that advises the Governor on climate change issues throughout the state and works to make Vermont resilient and adaptive in the face of climate change. One of the strengths of this body is that it engages the highest level of individuals from their respective agencies:[14] the Agency of Natural Resources; the Agency of Administration; the Agency of Agriculture, Food and Markets; the Department of Buildings and General

[10] New England Governors & Eastern Canadian Premiers. *Resolution 33-3: Resolution Concerning Climate Change*. 2009. 33rd Annual Conference of New England Governors & Eastern Canadian Premiers.
[11] Douglas, Jim. "Vermont Governor's Commission of Climate Change." Executive Order #05-11, 5 Dec 2005
[12] Appendix 2: Plenary Group Recommendations & Appendices to the Governor's Commission on Climate Change, Final Report.
[13] Shumlin, Peter. "Governor's Climate Cabinet." Executive Order #07-05, 17 May 2011.
[14] Woods, B., 2012. Personal Communication.

Services; Agency of Commerce and Community Development; the Department of Economic, Housing and Community Development; the Department of Public Service; the Agency of Transportation; and the Department of Health. Although a new group, the Climate Cabinet has a lot of opportunity to provide a different framework for action.[15,16]

Report Outline

Climate change adaptation is a relatively new topic of discussion in the state of Vermont and although some infrastructure is in place to address it, no dramatic measures have been taken. The flooding events of May and August 2011 exposed much vulnerability—especially within the transportation and housing sectors in Vermont—and brought increased attention to the climate adaptation discussion.[17] The following sections address possibilities for climate change adaptation within the spheres of transportation and housing within Vermont. Each section starts with a policy brief for the state of Vermont synthesized from our research, followed by guidelines and suggestions from federal and state-level agencies on transportation and housing and the areas in which Vermont is already taking measures which can be considered climate adaptive.

[15] Minter, S., 2012. Personal Communication.
[16] Mackay, N., 2012. Personal Communication.
[17] Woods, pers. comm.

II. Post-Tropical Storm Irene Implications for Climate Adaptive Transportation Policy in Vermont

A. TRANSPORTATION POLICY BRIEF: Climate Adaptive Policy for Transportation in Post-Irene Vermont, May 2012

Vermont has taken careful notice of the climate change science that has been provided over the past few decades and has taken a leadership role in environmental concerns. The recent flooding in Vermont brought on by Tropical Storm Irene has increased the salience of resilience and adaptation strategies, and has added these concerns to the existing mitigation efforts being undertaken in order to address climate change. According to the Agency of Natural Resources in Vermont, Tropical Storm Irene caused between $175 and $250 million in damages to the highway system, roads and bridges. Another estimated $20 million of damage was caused to public railroad systems with 66 private railway locations requiring repairs of unknown amounts to their respective owners. It is for these reasons that transportation adaptation should play a significant role within adaptation related discourse in post-Tropical Storm Irene Vermont.

Recommendations:

Conduct economic and physical risk assessments of climate change concerns to transportation infrastructure across the state with particular emphasis on the difference between "adaptation" versus "no adaptation" scenarios. Create a centralized resource of existing assessments from all relevant agencies and entities in the form of a data clearinghouse. Prioritize results of assessment for focus on immediate hazard areas for action and policy implementation.

Coordinate stakeholder adaptation strategies and interests through the existing infrastructure of the Climate Cabinet in order to collaborate on strategic efforts to approach immediate hazard areas through policy, while engaging all parties with vested interests in the target areas. Retain close communication with town selectboards and regional planning commissions throughout the policy collaboration process.

Implement structural reforms on existing infrastructure identified as contributing to the vulnerability of transportation systems with close consideration of individual town requirements for the retention of historical infrastructure.

Incentivize the use of new materials and innovative design for new infrastructure that do not increase vulnerability to climate change such as non-temperature dependent construction materials and larger hydraulic openings over waterways.

Integrate strategies for ecologic protection and resilience in all aspects of transportation action by conducting enhancements such as restoring wetlands, shoreline features, and flood storage capacity in order to restore the natural hydraulic features of the watersheds.

Cost:

Adaptation risk assessment, policy planning and implementation, and outreach will all require funds over and above those already afforded by the Department of Transportation.

The **High Meadows Fund** is an organization that supports environmental conservation through social entrepreneurship. Their current focus areas are decreasing fossil fuel use in buildings and transportation, increasing local food consumption, and supporting smart land use. Although the High Meadows Fund has not yet explicitly addressed climate change adaptation as a focus, it can be addressed under smart land use. This is not a source of funding for governments. Rather it is designed for 501(c)(3) organizations. The High Meadows Fund is therefore a resource for local organizations invested in community improvements. There are many other organizations like the High Meadows Fund willing to support community initiatives (see pp. 181-182). The **Town Highway Budgets** and **State Bridge and Highway Program** can integrative adaptive methods into their daily operations.

Additionally at the state level, there are many opportunities for grants or re-appropriation of money to support climate adaptive programs. These include the **Department of Environmental Conservation, Watershed Management Division: Water Quality Grant Opportunities** or the **Vermont Agency of Transportation Enhancement Grant Program** (as identified in proposed H-770) or the **Vermont Agency of Transportation Research Board**.

From the federal level, there are a variety of funding sources for transportation adaptation. These include the **Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant Program** or the **Emergency Management Planning Grants**, distributed by Vermont Emergency Management. FEMA Mitigation grants are not specifically designed for climate adaptation, but proposals for funding that address adaptation and the elimination of risk will be considered. However in the wake of Irene and other disasters, damage related to these types of events may be more likely to receive federal aid from FEMA and this provides the opportunity for more resilient reconstruction. Other federal programs include the **National Flood Insurance Program** that assists flood victims who have had their property previously insured and **SAFETEA-LU** (most likely to be replaced by MAP-21). SAFETEA-LU is the Safe Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, which guarantees funding for highways and public transportation. SAFETEA-LU aims to promote efficient and effective transportation programs while allowing state and local transportation authorities more flexibility in decision-making for resolving transportation problems in their communities.[18]

Vermont as a Leader

Since the restoration of natural hydraulic systems and greater utilization of existing road and transportation networks are measures that strongly overlap with the goals of reducing energy consumption and increasing efficiency, there are no foreseeable contradictions between mitigation and adaptation when it comes to transportation—only opportunities for synergy. For this reason, Vermont's already elevated status as a leader on climate change mitigation will serve as an ideal launching point for transportation adaptation policy.

[18] Summary of Highway Provisions in SAFETEA_LU. Federal Highway Administration. Office of Legislation and Intergovernmental Affairs. August 25, 2005. http://www.fhwa.dot.gov/safetealu/summary.htm

B. Climate Change Adaptation and Transportation

The Transportation Research Board Division (TRBD) on Earth & Life Studies is a committee within the National Research Council, a non-governmental organization with the mission to "improve government decision making and public policy, increase public understanding, and promote the acquisition and dissemination of knowledge in matters involving science, engineering, technology, and health. The Research Council's independent, expert reports and other scientific activities inform policies and actions that have the power to improve the lives of people in the U.S. and around the world."[19] The committee lists the most important potential impacts of climate change on transportation in the US as the following:[20]

TABLE S-1 **Potential Climate Changes and Illustrative Impacts on Transportation**

Potential Climate Change	Examples of Impacts on Operations	Examples of Impacts on Infrastructure
Increases in very hot days and heat waves	Impact on lift-off load limits at high-altitude or hot-weather airports with insufficient runway lengths, resulting in flight cancellations or limits on payload (i.e., weight restrictions), or both Limits on periods of construction activity due to health and safety concerns	Thermal expansion on bridge expansion joints and paved surfaces Concerns regarding pavement integrity (e.g., softening), traffic-related rutting, migration of liquid asphalt Rail-track deformities
Increases in Arctic temperatures	Longer ocean transport season and more ice-free ports in northern regions Possible availability of a northern sea route or a northwest passage	Thawing of permafrost, causing subsidence of roads, rail beds, bridge supports (cave-in), pipelines, and runway foundations Shorter season for ice roads
Rising sea levels, combined with storm surges	More frequent interruptions to coastal and low-lying roadway travel and rail service due to storm surges More severe storm surges, requiring evacuation or changes in development patterns Potential for closure or restrictions at several of the top 50 airports that lie in coastal zones, affecting service to the highest-density populations in the United States	Inundation of roads, rail lines, and airport runways in coastal areas More frequent or severe flooding of underground tunnels and low-lying infrastructure Erosion of road base and bridge supports Reduced clearance under bridges Changes in harbor and port facilities to accommodate higher tides and storm surges
Increases in intense precipitation events	Increases in weather-related delays and traffic disruptions Increased flooding of evacuation routes Increases in airline delays due to convective weather	Increases in flooding of roadways, rail lines, subterranean tunnels, and runways Increases in road washout, damages to rail-bed support structures, and landslides and mudslides that damage roadways and tracks Increases in scouring of pipeline roadbeds and damage to pipelines
More frequent strong hurricanes (Category 4–5)	More frequent interruptions in air service More frequent and potentially more extensive emergency evacuations More debris on roads and rail lines, interrupting travel and shipping	Greater probability of infrastructure failures Increased threat to stability of bridge decks Impacts on harbor infrastructure from wave damage and storm surges

[19] Welcome to the National Research Council. *The National Academies.* http://www.nationalacademies.org/nrc/

[20] Potential Impacts of Climate Change on US Transportation. Transportation Research Board Special Report 290. *National Research Council of the National Academies.* 2008. Washington D.C. http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf

Despite these national projections, the committee emphasizes the importance of state-specific analyses of the effects of climate change on transportation. Over the past decade in particular, the federal government has begun to include climate change concerns into the policy recommendations made by its agencies, and transportation is no exception. The Department of Transportation has statewide offices that promote federal regulations concerning climate change adaptation and mitigation, which in turn promote the implementation of statewide policy (Figure 1).

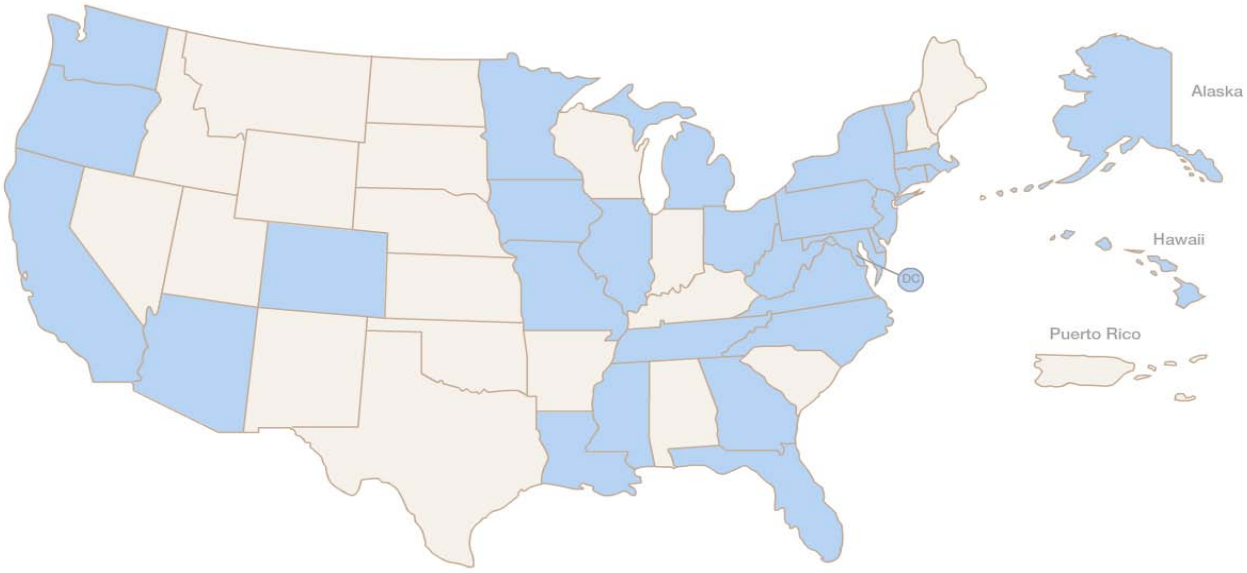

Figure 1. The states highlighted in blue represent those with Departments of Transportation which include climate change documentation. [21]

States that have done the most in terms in climate change adaptation in transportation structure tend to be the states that are most concerned about the immediate impacts of sea level rise and other climate change risks. Such coastal states include California, Massachusetts and Connecticut, which all are concerned given the high economic and social capital that exists along these coasts. Though Vermont does not have a coastline, it has multiple shorelines along lakes that are equally prone to flooding due to rising water levels in lakes from excessive rain in flooding events. Coastal flooding concerns seem to be the major push for adaptation measures in the states that are most advanced in transportation adaptation to climate change. These are also the states whose

[21] "Transportation and Climate Change Resource Center." American Association of State Highway and Transportation Officials. http://climatechange.transportation.org/tools/state_by_state/.

recommendations have proven most relevant to Vermont despite our location due to the similarities in adaptation strategies that are required for flood resilience in general, whether it come from sea level rise or increased precipitation (see Section II.C).

The Federal Highway Administration (FHWA) produced a report in July 2008 called "Integrating Climate Change into the Transportation Planning Process" which describes the effects of climate change on transportation concerns and outlines what individual states are doing regarding mitigation and adaptation. The report concludes that many states are making advances in the area of mitigation through GHG emissions reduction assessments and policy implementation. However, in the adaptation arena the report states:

"Most transportation agencies are not currently seeking to incorporate climate change adaptation measures into long range planning. While there is general recognition of the threat that climate change poses to transportation infrastructure, agencies feel that significant impacts are at least several decades away, so there is little sense of urgency. In addition, the large uncertainty in the location and magnitude of impacts makes agencies reluctant to take major action on adaptation, given the multitude of other pressing demands for DOTs and their funding limitations. Over the next several years, as more sea level rise studies are completed and scientists improve the precision of climate change forecasts, adaptive responses are likely to be more substantially incorporated into long range planning."[22]

Nonetheless, federal bodies are making recommendations to kick-start the process of transportation adaptation to climate change nationwide.

Climate Change Adaptation within the Structure of Vermont Transportation

In the absence of a coastline and the associated immediate threat of sea level rise, there must be other factors which will inspire a greater sense of climate adaptation urgency in the state of Vermont. In the post-Irene era, this factor seems to be the increased likelihood of major flood events and the threat of constant damage to communities if management practices do not change. The major flood of events of May and August 2011 increased awareness of and exposed major vulnerabilities in Vermont's transportation infrastructure.[23] As mentioned in our introduction, climate change adaptation has recently received increased attention within the region and the state. Based

[22] Integrating Climate Change into the Transportation Planning Process. Federal Highway Administration. Prepared by ICF International. July 2008. http://www.fhwa.dot.gov/hep/climatechange/climatechange.pdf
[23] Woods, pers. comm.

on the suggestion of the GCCC to produce plans for climate change adaptation, in 2010[24] various governmental departments produced white papers addressing the effects of climate change on their respective industries.[25] Gina Campoli, Environmental Policy Manager for the Vermont Agency of Transportation, has identified changes in temperature, water, and wind patterns as the primary consequences of climate change that will impact transportation infrastructure within the state of Vermont. Changes in these factors have been determined to cause the following impacts on transportation:[26]

- Flooding and erosion of low lying roads, railroads and other infrastructure
- Changes in the intensity and frequency of storm events necessitate that culverts, bridges, erosion controls and storm water systems be designed and maintained to adequately handle the associated increased flow, sediment and debris transport
- Increased stream flow results in increased bridge scour
- Increased moisture and corrosion damage on pavements and structures
- Failure of pavement and bridge expansion joints
- Effects on roadbed and pavement longevity from an increase in freeze thaw cycles.
- Increased pavement rutting and vehicle hydroplaning potential
- Increases in extreme wind events and associated downed trees, power lines and debris blocking roadways, waterways and Right of Way (ROW)
- Higher wind loading on bridges
- Increased emergency preparedness and evacuation demands
- Changing winter maintenance demands due to more or less snow or an increase in freeze events
- Compromised availability and the need to stockpile diesel fuel, salt, and sand
- Effects of new exotic species and longer growing season on ROW vegetative management and stream bank longevity

[24] Appendix 2: Plenary Group Recommendations & Appendices to the Governor's Commission on Climate Change, Final Report.
[25] Climate Change Adaptation. *Climate Change Team.* Vermont Agency of Natural Resources. 2012. http://www.anr.state.vt.us/anr/climatechange/Adaptation.html.
[26] Campoli, G., 2011. VTrans Climate Change Adaptation White Paper Topic Outline. Draft. *Climate Change Team.* Vermont Agency of Natural Resources.

The Agency of Transportation White Paper is an initial assessment of the projected damages to transportation infrastructure. The document goes on to list areas in which their knowledge is limited, particularly in understanding and gauging worldwide or regional climate change models and applying them to a watershed or bioregional level.[27] Since the Agency of Transportation (VTrans) is only in the initial steps of understanding the frequency of physical consequences of climate change, it has yet to take any actions for climate change adaptation.[28] Meanwhile, VTrans is looking to the federal government and the regulations in the National Environmental Policy Act to provide guidance for the next steps forward. A major concern for climate change adaptation for VTrans is the source of funding necessary to pursue climate change adaptation policies.[29] Currently adaptation is not a regulatory measure, and Sue Minter, Deputy Secretary of the Agency of Transportation, highlighted in discussions the limited resources dedicated to the topic of adaptation with other, more immediate issues at hand.[30]

In moving forward, the White Paper concludes with the suggestion for the establishment of a risk-assessment process or cost-benefit analysis[31] to help prioritize and act on projects related to climate change adaptation.[32]

[27] Campoli, 2011.
[28] Campoli, pers. comm.
[29] Campoli, 2011.
[30] Minter, pers. comm..
[31] Refer to Chapters 2 and 3 of this report for more information on cost-benefit analyses.
[32] Campoli, 2011.

C. General Climate Change Adaptation Recommendations for Transportation from Other States

The TRBD published a report on the potential impacts of climate change on transportation and made recommendations for adaptation to such changes in order to create a more resilient society.[33] In the report, *Potential Impacts of Climate Change on US Transportation,* the TRBD stated the following as recommendations for the implementation of nationwide adaptation:

- State and local governments and private infrastructure providers will need to incorporate adjustments for climate change into long-term capital improvement plans, facility designs, maintenance practices, operations, and emergency response plans.
- Design standards will need to be re-evaluated and new standards developed as progress is made in understanding future climate conditions and the options for addressing them.
- Transportation planners will need to consider climate change and its effects on infrastructure investments. Planning timeframes may need to extend beyond the next 20 or 30 years.
- Institutional arrangements for transportation planning and operations will need to be changed to incorporate cross-jurisdictional and regional cooperation.
- Re-evaluation of all transportation functions will need to incorporate climatic change and its repercussions – planning, programming, environment, location, design, engineering, construction, operations, emergency planning – and budgeting.

D. Risk Assessment and Implementation Framework from Other States

Why Adapt?

The Connecticut Department of Transportation recommends that states perform a risk assessment of the impacts on transportation of not adapting to climate change. This highlights the disadvantages of non-action and creates the foundation for substantiating immediate action. Such an assessment should model the societal costs of delayed or

[33] Potential Impacts of Climate Change on US Transportation. Transportation Research Board Special Report 290.

inappropriate response to climate change and Connecticut highlights the following areas as most crucial within their state:

i. Agriculture:
   - Delayed agricultural inputs due to disabled transportation networks hinders and halts the production of agricultural goods, while those ready for processing or sale will spoil (animal feed and labor costs also become losses)

ii. Public Health
   - Obstructed transportation impedes treatment of patients and access to care
   - Compromised evacuation procedures and sheltering[34]

Along similar lines, the government of California has produced a report of recommendations involving a similar assessment model with a more detailed plan for implementation in order to move ahead with policy design:

a. Vulnerability and Adaptation Planning – BTH (Business, Transportation and Housing Agency) and CALTRANS will develop a climate vulnerability plan that will assess how California's transportation infrastructure facilities are vulnerable to future climate impacts, assess climate adaptation options, prioritize for implementation, and select adaptation strategies to adopt in coordination with stakeholders. This plan will be coordinated with an updated climate mitigation plan that will act as BTH's and CALTRANS' overall transportation climate policy.

   i. Develop a transportation use "hot spot" map – CALTRANS will research and identify transportation "hot spots", using appropriate study efforts, to identify across the state where the mixture of climate change impacts, population increases, and transportation demand increases will make

[34] Connecticut Department of Transportation (CT DOT). 2009. Connecticut on the Move. Strategic Long-Range Transportation Plan 2009-2035.
http://www.ct.gov/dot/lib/dot/documents/dpolicy/lrp/2009lrp/lrp2009_final_document_june_2009.pdf

communities most vulnerable to climate change impacts. CALTRANS will include in this analysis how the lowest-income communities in hot spot areas will be impacted.

b. Economic Impacts Assessment – Complete an "overall economic assessment for projected climate impacts on the state's transportation system and other related infrastructure along transportation corridors as appropriate under a "do nothing" scenario and under climate policy scenarios identified by BTH/CALTRANS.

   i. Prepare a list of transportation adaptation strategies or measures based on the "hot spot" map and prepare an economic assessment and cost-benefit analysis for these strategies vs. a do-nothing scenario[35]

When to Adapt

The state of Massachusetts highlights the need for identifying lead-time for adaptive construction. Since different types of facilities have varying life spans, those timeframes need to be translated into lead times for infrastructure replacement and rehabilitation. The amount of time needed to permit, repair, improve, or build infrastructure will vary and should be identified before action is taken.[36] Also, the life-span of infrastructure that was put in place without climate change considerations needs to be updated in order to be appropriately maintained. All this must be determined before any action is taken on existing infrastructure and before new systems can be put in place.

How to Adapt (Criteria to Consider, and Who's Considering It)

A core part of the adaptation process is initial data collection and monitoring, which outlines the current state of affairs in order for upgrades to be made to increase the resilience of transportation infrastructure. The state of Maryland outlines several asset management criteria that should be looked at in existing infrastructure:

[35] Statewide Adaptation Strategy- Chapter 10: Transportation and Energy Infrastructure. Government of California. http://resources.ca.gov/climate_adaptation/docs/Statewide_Adaptation_Strategy_-_Chapter_10_-_Transportation_and_Energy_Infrastructure.pdf

[36] Massachusetts Climate Change Adaptation Report. Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee. http://www.onlineethics.org/File.aspx?id=25960

- Age
- Elevation
- Materials used
- Design lifetime and stage of life
- FEMA maps of past damage
- Current and historical performance and conditions
- Vegetation survey
- Soil type
- Average daily traffic
- Bridge state route
- Scour criticality
- Length/width of bridge[37]

The state of Alaska has as its first priority to collect data and monitor the current state of transportation infrastructure and share it amongst the various agencies involved in climate change policy implementation and the general public.

- Coordinated data collection, analysis and monitoring
    - Analysis of existing condition of public infrastructure
        - What are environmental conditions where it is located?
    - Use information to prepare forecasts and trend analysis yielding up-to-date rates of erosion, permafrost thaw, and flooding by region
    - Share information in a usable format
        - Standardize information using baselines and benchmarks
        - Collect soil temperature, air temperature, precipitation, surface runoff, shore-fast sea ice duration and extent, coastal wind speed and duration
        - Prepare projections of climatic and local environmental conditions that include up-to-date rates and maps of soil temperatures, coastal and riverine erosion, event intensity and 100 year floodplains

[37] Climate Change Adaptation. Maryland State Highway Administration. Slide presentation by Gregory Slater at the 2011 Transportation Research Board Annual Meeting. January 2011. climatechange.transportation.org/tools/state_by_state/

- Integrate knowledge among agencies; review agency plans for climate resilience
- Develop a clearinghouse of data [38]

Connecticut outlines the procedures for structural reforms of transportation infrastructure and the reassessment of watershed management practices to reduce the impacts of flooding. The state prioritizes transportation due to the detrimental effects of failed transportation infrastructure on agriculture and public health, which are particular concerns in Connecticut as well as Vermont:

Structural reforms

- Use materials that do not increase vulnerability
- Construction materials that are not temperature-dependent
- Larger hydraulic openings for bridges over waterways
- Greater pavement crowns to move runoff off pavement more quickly
- Design additional in-system detention to meter runoff outflow
- Design more robust pavement markings that can be seen during wet/night conditions
- Provide larger capacity pumps/pump stations for below grade freeways to prevent flooding
- Eliminate bridge design elements that could make a bridge scour critical – i.e. piers in the river, spread footings, use more sheet piling left in place

Following the reassessment of watershed management in order to reduce flooding impacts, it is important to reassess and enhance all natural systems in order to reduce anthropogenic impacts on the natural behaviors of environmental cycles. The state of Massachusetts lays out how this should be done:

[38] Alaska's Climate Change Strategy: Addressing Impacts in Alaska, Adaptation Advisory Group to the Alaska Climate Change Sub-Cabinet, January 2010. http://www.climatechange.alaska.gov/aag/aag.htm

- The state should provide protection and resilience of infrastructure to climate change impacts by enhancements such as restoring wetlands, coastal features, and flood storage capacity. It should restore the natural hydraulic features of watersheds to increase resiliency and capacity redundancy in wastewater systems, water supplies, and storm water management resources.
- Expand the use of the statewide GIS-based system asset maps by combining them with updated floodplain mapping and revised peak flood flow calculations.
- These maps can then be used to update hydrologic and hydraulic analyses statewide, including engineering methods used in the calculation of peak flood flow rates, to reflect influence of climate change-induced events.[39]

Now that the planning side is complete in terms of physical geography, existing infrastructure and projected climate change impacts, the state of California recommends the incorporation of this information into the planning involved in existing transportation & investment decisions:

Near -Term and Long-Term Actions:

Integrate Mitigation and Adaptation System-wide: CALTRANS will develop and incorporate climate change mitigation and adaptation policies and strategies throughout state strategic, system and regional planning efforts. These will be included in key phases of the following planning and project development phases when appropriate:

i. Strategic Planning (Governor's Strategic Growth Plan and California Transportation Plan)
ii. System Planning (i.e., District System Management Plan, Inter-regional Strategic Plan, Corridor System Management Plan, and Transportation Concept Report)

[39] Massachusetts Climate Change Adaptation Report. Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee. http://www.onlineethics.org/File.aspx?id=25960

iii. Regional Transportation Planning (Regional Transportation Plan Guidelines and Regional Blueprint Planning)

iv. Project Planning (Project Development Procedures Manual, Project Initiation Document, Project Report, Design and engineering standards, Environmental Guidelines)

v. Programming (State Transportation Improvement Program, State Highway Operations and Protection Program, California Transportation Commission State Transportation Improvement Program Guidelines)[40]

As a result of incorporating new information into planning, it is important to guide this information and planning to a policy outcome that can be implemented at a private as well as a public level, which is highlighted in the state of Washington's recommendations:

Create statewide policy to guide private and local actions:

a. Return some coastal and floodplain areas to nature.
b. Restrict development in floodplains and vulnerable coastal areas.
c. Determine threshold for when state will not invest in at-risk locations; tie to project life.[41]

Who Should Adapt

For all states referenced in this report, climate adaptive transportation actions were undertaken by state level transportation boards.

Cost of Adaptation

The costs of adaptation will vary depending on the scale of adaptation measures as well as the state that they are being performed in. California suggests that costs be

[40] Statewide Adaptation Strategy- Chapter 10: Transportation and Energy Infrastructure. Government of California. http://resources.ca.gov/climate_adaptation/docs/Statewide_Adaptation_Strategy_-_Chapter_10_-_Transportation_and_Energy_Infrastructure.pdf

[41] Washington State Climate Change Response Strategy. Interim Recommendations of the Built Environment: Infrastructure & Communities Topic Advisory Group (TAG). January 2011. http://www.ecy.wa.gov/climatechange/2011TAGdocs/I2011_interimreport.pdf

assessed in relation to the benefits that ensue from implementation of the policy, as costs should be compared relative to costs avoided:

a. Economic Impacts Assessment – Complete an overall economic assessment for projected climate impacts on the state's transportation system and other related infrastructure along transportation corridors as appropriate under a "do nothing" scenario and under climate policy scenarios identified by BTH/CALTRANS.
b. Prepare a list of transportation adaptation strategies or measures based on the "hot spot" map and prepare an economic assessment and cost-benefit analysis for these strategies vs. a do nothing scenario.[42]

Short-term vs. Long-term Resilience

In terms of short-term resilience and adaptation planning, the state of Massachusetts recommends protecting existing infrastructure; in the long-term, they recommend implementing engineering solutions. In protecting existing infrastructure, modifications include elevating, armoring, modifying, or relocating critical infrastructure. Airport, mass transit, port, and highway agencies should consider sizing storm water management structures (e.g., pipes, culverts, outfalls) for future storm events and balancing upfront costs of incrementally larger structures today with the future costs of replacing an entire drainage system. In the longer term, The Massachusetts Department of Transportation and Massachusetts Port Authority should work with regional and municipal agencies to identify, develop and implement solutions—including reconstruction, removal, or relocation of vulnerable infrastructure—to protect existing assets from climate change impacts in the long- and short-term. Also in the long-term, the state should revise standards to be consistent with guidelines reflecting climate considerations issued by such entities as the American Association of State Highway and Transportation Officials, Federal Highway Administration, American Public Transit Association, Federal Transit Administration, U.S. Department of Transportation Maritime Administration, and the Federal Aviation Administration.[43]

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[42] Statewide Adaptation Strategy- Chapter 10: Transportation and Energy Infrastructure. Government of California. http://resources.ca.gov/climate_adaptation/docs/Statewide_Adaptation_Strategy_-_Chapter_10_-_Transportation_and_Energy_Infrastructure.pdf

[43] Massachusetts Climate Change Adaptation Report. Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee. http://www.onlineethics.org/File.aspx?id=25960

In order to minimize risks to vulnerable transportation infrastructure, the state of California recommends that the following short-term actions be conducted:

a. Buffer Zone Guidelines - Develop guidelines to establish buffer areas and setbacks to avoid risks to structures within projected "high" future sea level rise or flooding inundation zones.
b. Stormwater Quality - Assess how climate changes could alter size and design requirements for stormwater quality best management practices.[44]

Approach to Disaster Preparedness

The state of California outlines an emergency preparedness strategy in order to incorporate climate change impact considerations into disaster preparedness planning for all transportation modes:

Near -Term and Long-term Actions:

a. Emergency Preparedness – CALTRANS provides significant emergency preparedness abilities for all transportation modes across the state. The transportation system is sensitive to rapid increases in precipitation, storm severity, wave run-up and other extreme weather events. CALTRANS will assess the type of climate-induced impact information necessary to respond to district emergencies. Results will be incorporated into existing operations management plans.

b. Decision Support – CALTRANS will identify how climate impact information can be integrated into existing Intelligent Transportation Systems and Transportation Management Center operations.[45]

The state of Michigan expresses concern over the increased probability of intense storms and hotter and drier summers due to climate change and recommends the following:

Design Considerations: More Intense Storms

Strategy: Design assets that are less impacted by effects of climate change include:

[44] Statewide Adaptation Strategy. California
[45] Statewide Adaptation Strategy. California

- Larger hydraulic openings for bridges over waterways
- Heavier and lengthier armoring of river and stream banks and ditches to prevent erosion
- Investigate greater pavement crowns to move runoff off of pavement quicker
- Design of additional in-system detention to meter runoff outflow
- Eliminate bridge design elements that could make a bridge scour critical – i.e. piers in the river, spread footings, use more sheet piling left in place
- Design terraced vegetated slopes using a variety of plant species
- Design more robust pavement markings that can be seen during wet/night conditions
- Larger capacity pumps/pump stations for below grade freeways to prevent flooding

Strategy: Protect motorists, workers, and the environment from hazards created in work zone by strong weather events

- Stronger specifications for protection of work under construction that require contractor response plans for work zones impacted by high intensity storm

Strategy: Protect work in progress from effects of higher temperatures for both short term and long-term durability

- Encourage more night/cooler weather work to prevent damage such as slab curling, premature cracking, loss of air entrainment in concrete pavements, rutting and flushing in asphalt pavements

<u>Design Considerations: Hotter, Drier Summers</u>

Strategy: Design tougher, more resilient, lower maintenance roadways, bridges, facilities and roadsides

- Design lower maintenance bridge expansion
- Design seed/vegetation mixtures that create denser, deep-rooted vegetation mat that is more erosion resistant

- Eliminate monoculture roadside vegetation designs that may not survive extended drought periods or invasive species attack
- Ensure all roadside building designs are LEED certified or modified to be energy to be energy efficient [46]

E. Risk Assessment and Implementation Framework Already Existing in Vermont

Why Adapt?

On the state government level, there is an acceptance that climate change will impact the transportation sector[47] and the way the Agency of Transportation functions.[48] With this acceptance, many assessments of climate predictions for the Vermont and New England region were conducted to get a comprehensive understanding of the extent of the impact. [49,50,51,52,53]

With an understanding of the predicted outcomes of climate change, other state climate adaptation models suggest undertaking sector specific risk assessments to model how the predictions will affect infrastructure within a certain industry.

From communication with Joe Segale, Policy and Planning Manager of VTrans[54] and Noelle Mackay, Commissioner of the Department of Economic, Housing and Community Affairs (DEHC),[55] it appears that they do not have good metrics to assess general infrastructural risk, and risk assessment and a clear connection to climate change has not yet been considered. Since the discussion of climate change adaptation is

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[46] Climate Change Adaptation Issues in Highway Operations Michigan Department of Transportation. TRB Webinar. 2011. http://climatechange.transportation.org/pdf/state_by_state/GCC_Michigan_Climate_Adaptation_Slides_for_TRB_Webinar_4_7_11.pdf

[47] Doherty, Ray., 2012. Personal Communication.

[48] Campoli, 2011.

[49] Betts, Alan. 2011. Vermont Climate Change Indicators. *Weather, Climate and Society*. 3, 106-115.

[50] Stager, C. and Mary Thill. Climate Change in the Champlain Basin: What natural resource managers can expect and do. New York: *The Nature Conservancy*, 2010.

[51] Hayhoe, Katherine, et. al., 2006. Past and future changes in climate and hydrological indicators in the U.S. Northeast. *Climate Dynamics*, 28, 381–407.

[52] Frumhoff, Peter, et. al., 2007. Confronting Climate Change in the US Northeast. Cambridge: UCS Publications.

[53] Hayhoe, Katherine, et. al., 2008: Regional climate change projections for the Northeast USA. *Mitigation Adaptation Strategies Global Change*, 13, 425–436.

[54] Segale, J., 2012. Personal Communication.

[55] Mackay, pers. comm.

relatively recent in Vermont, it is unlikely that assessments have been made clearly mentioning the link between the threats and their climate forcings.

Of the predictions for climate change in Vermont, flooding will be the consequence with the greatest frequency, damage, and cost to the region.[56] As mentioned previously in Chapter 3, the historic pattern of development and flood recovery efforts has made the state's transportation infrastructure more vulnerable to flood events. As infrastructure is rebuilt in locations of know previous damage, towns, counties, and states are taking on the financial, social, and environmental costs again and again after every flood event.

When to Adapt

In the state of Vermont, the planning for adaptation (but mainly mitigation) is more commonly seen in the development of large-scale infrastructure or buildings. Our community partners expressed their frustration with proposing alternative transportation routes due to the extent of bureaucracy involved with the well-intentioned Environmental Impact Statements and associated costs. With the influx of federal money into the region, it has been possible in some cases to use FEMA money to rebuild or relocate certain infrastructure to be more adaptive,[57] although in most cases it is possible to receive more federal money if the new infrastructure is the same as the infrastructure being replaced, an action which is counterproductive for climate change adaptation.[58] In the case of the Irene transportation recovery effort, damaged infrastructure was rebuilt to its previous standards. This method perpetuates vulnerabilities and results in repeat damage, but the reality of the recovery effort is that functioning roads and transportation infrastructure are the first demands due to the immediate necessity of access to resources.

How to Adapt (Criteria to Consider, and Who's Considering It)

Many of the criteria for assessment addressed in other states' suggestions are already being undertaken in various organizations and agencies within Vermont. In this sense, basic risk assessments are being done throughout the state, but they are not clearly

[56] Kline and Dolan, 2010
[57] Minter, pers. comm.
[58] "Alternate Projects" *Public Assistance.* FEMA. http://www.fema.gov/government/grant/pa/9525_13.shtm.

stating the connection to climate change or addressing changing climate patterns and how these will affect infrastructure in the future. The criteria to consider, as identified by the Maryland State Highway Administration, should include but not be limited to:

- Age
- Elevation
- Materials used
- Design lifetime and stage of life
- FEMA maps of past damage
- Current and historical performance and conditions
- Vegetation survey
- Soil type
- Average daily traffic
- Bridge state route
- Scour criticality
- Length/width of bridge[59]
- Analysis of existing condition of public infrastructure

The Vermont Geomorphic Assessments conducted by the Department of Environmental Conservation (DEC) represent a fairly comprehensive source for the relevant geographic variables and shed light on how infrastructure is impacted by fluvial geomorphic patterns and events.[60] Shane Csiki, of the New Hampshire Geologic Society, identified the geomorphic assessment as a model for other states.[61] One of the recent additions to the assessment is the 2009 Bridge and Culvert Assessment Protocol, which provides clear instructions on how to proceed with assessment (Figure 2).[62]

[59] Climate Change Adaptation. Maryland State Highway Administration.

[60] "Geomorphic Assessment." *Watershed Management Division.* Vermont Department of Environmental Conservation. http://www.vtwaterquality.org/rivers/htm/rv_geoassess.htm.

[61] Csiki, Shane. "Fluvial Erosion Hazards in the New Hampshire: Effects from Irene ad Choices for the Future." Lecture. Northeastern Section Geologic Society of America Conference 2012, Hartford, Connecticut. 19 March 2012

[62] Vermont Agency of Natural Resources. *Vermont Stream Geomorphic Assessment: Appendix G, Bridge and Culvert Assessment.* March 2009.

Floodplain filled by roadway approaches: Circle the approximate amount of floodplain filled up to or above the flood prone elevation by the roadway approaches on either side of the structure. The **flood prone elevation** is the height equal to 2 times the maximum bankfull channel depth measured above the streambed (see Phase 2, Step 2.7).

Entirely = More than ¾ of the floodplain width is occupied by approach ramps (see Figure 4)
Partially = Between ¼ and ¾ of the floodplain width is occupied by approach ramps (see Figure 3)
Not Significant = Less than ¼ of the floodplain width is occupied by approach ramps

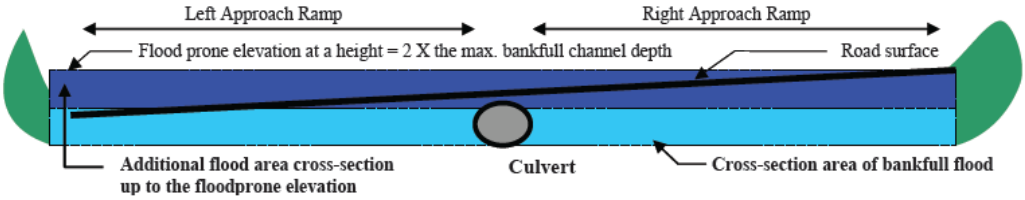

Figure 3. Valley cross-section where the left and right approach ramps partially occupy floodprone area.

Figure 4. Cross-section view of culvert site where the left and right approach ramps entirely occupy the floodprone area.

Solid Black Line = elevation of road surface and approaches to culvert site

Dashed White Line = flood prone elevation at a height that is 2 X the maximum bankfull channel depth (height **B** as measured from the bed)

Dotted White Line = maximum depth from the stream bed to the elevation of bankfull (height **A**). See Channel Width discussion.

Stream Geomorphic Assessment Handbooks
March, 2009
- G7 -
VT Agency of Natural Resources

Figure 2. Excerpt from the Bridge and Culvert Assessment.[63]

Vermont's Watershed Management Division (WSMD) addresses many of the criteria identified in the statewide survey of "How to Adapt." As a subset of the Department of Environmental Conservation, the WSMD's current focus has to do with phosphorus loading in Lake Champlain. There is a subset of WSMD projects done in conjunction with VTrans known as the Better Backroads Program.[64] The majority of these projects address erosion and bank stabilization for at-risk transportation

[63] Ibid.
[64] "Ecosystem Restoration Program Projects." *Watershed Management Division.* Vermont Department of Environmental Conservation. http://www.anr.state.vt.us/dec/waterq/erp/projects/basinprojects-programlist.cfm.

infrastructure. Other concerns, such as floodplain and buffer management, which will ultimately help mitigate flood damage, are also under the purview of the WSMD.[65]

Like most Vermont initiatives, much of this watershed work is based on the consequences of ecosystem change on the area. Little work has been done on connecting watershed management practices to larger scale transportation infrastructure. In regards to ecological consequences of climate change, Stager and Thill conclude that Vermont already has many proactive conservation practices in place, but there is a need for a greater urgency and application of conservation and adaptation policies, especially ones that require ecosystem monitoring. Key suggestions relevant for our work include that (1) environmental monitoring in the context of ongoing and projected climate change should become a funding priority for the state government, and (2) there should be increased public education regarding climate change.[66] When applied to floodplain management, their climate adaptation suggestions have the possibility of positively influencing transportation infrastructure.

The VTrans Research Section's role is to address many innovative materials and issues in the transportation sphere.[67] For example, their research includes comparing various types of concrete or methods for slope stabilization. The Research Section has an opportunity to be innovative and adaptive with their work and really create long-term change. Thus far this has not been a venue to address climate change adaptation methods but it has the structure and mission to do so in the future. Another possible resource for innovative transportation projects can be the University of Vermont, Transportation Research Center (TRC).[68] Although most of their current climate associated projects are related to mitigation, with successful collaboration between VTrans, the TRC can be another resource for the consideration and trial of climate adaptive transportation measures.

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[65] "Watershed Management Division." *Watershed Management Division.* Vermont Department of Environmental Conservation. http://www.anr.state.vt.us/dec/waterq/wqdhome.htm.

[66] Bienkowski, Brian. "City lakes attract more airborne mercury than those further away." *Great Lakes Echo.* 23 January 2012. Web.

[67] "Materials and Research." *Program Development.* Vermont Agency of Transportation. 2012.http://www.aot.state.vt.us/progdev/sections/m&r%20info/M&RResearchCurrentProjects.htm.

[68] "Transportation Research Center." The University of Vermont. http://www.uvm.edu/~transctr/.

On the local level, there are many interested partnerships and organizations that are undertaking or facilitating assessments for the betterment of their communities. For example, the other research groups in our seminar worked in the towns of Plymouth and Hancock, where the White River Partnership has taken an active role in watershed assessment and river corridor planning.[69] Although not explicitly linked to climate change adaptation, the projects and concerns addressed by the White River Partnership and similar organizations around the state will benefit downstream communities and their transportation infrastructure in future flood events. Other organizations with similar goals include the Vermont River Conservancy[70] and the Vermont Land Trust.[71]

Irene related bills in the Vermont legislature have changed considerably since the beginning of the year. They have now been consolidated into one bill, S-202, that was recently approved. Some of the suggestions from other states—primarily regulations that support the natural hydraulic functions of watersheds and protects ecology—have been adopted into this bill. Key components of this bill include establishment of river corridor and floodplain management programs, and stricter guidelines for stream alteration.

Who Should Adapt

Much of the work currently identified by the Department of Environmental Conservation is in line with the ecological side of dealing with climate change adaptation. These practices can be more prolific if more resources are available, but the next step should be identifying current responsibilities of DEC that already directly address and work towards climate change adaptation. In regards to transportation infrastructure, the Agency of Transportation should be an active player in climate change adaptation. Like the DEC, VTrans has not made the link between current practices and climate change adaptation. VTrans should take on more responsibility in regards to risk assessment of infrastructure, focusing on how it will be affected by predicted trends, not just current ones.

Sue Minter, Noelle Mackay, and David Mears, Commissioner of the DEC, all identified a desire to incorporate large-scale adaptation actions and policies in their

[69] White River Partnership. South Royalton, Vermont. http://www.whiteriverpartnership.org/.
[70] For more information, see http://www.vermontriverconservancy.org/.
[71] For more information, see http://www.vlt.org/.

respective departments. This will require dramatic change for their departments, and although they mentioned the difficulty of making this happen due to many conflicts of interest and goals, they highlighted the desire for transformative ideas to completely integrate adaptation into current methods.[72, 73,74]

Vermont Emergency Management has addressed issues of climate change in their State Hazard Mitigation Plan.

Cost of Adaptation

Supporting the plethora of projects that would address climate adaptation in Vermont would require increased funding beyond what is already available as most agencies are already stretched thin in regards to what they are able to fund. Alongside the sources of funding identified by the working group on Repeat Damage (Chapter 3), additional sources of funding could include:

Municipal Level:

Many larger towns and cities in Vermont may have their own smaller, transportation or public works departments. These entities are responsible for the general day to day and minor maintenance of transportation structures and could therefore incorporate climate adaptive technologies or materials into their regular infrastructure.[75]

Local Businesses/ Community Organizations:

Within individual communities, there are smaller organizations and non-profits willing to support environmental projects throughout the state. Some examples of this include:

- High Meadows Fund[76]:
  The High Meadows Fund is an organization that supports environmental conservation through social entrepreneurship. Their current focus areas are decreasing fossil fuel use in buildings and transportation, increasing local food

[72] Minter, pers. comm.
[73] Mackay, pers. comm.
[74] Mears, D., 2012. Personal Communication.
[75] "Highway Division of Public Works." *Town of Middlebury.* http://www.middlebury-ct.org/Pages/PW_Highway.aspx/
[76] "High Meadows Fund" *Vermont Community Foundation. http://www.highmeadowsfund.org/.*

consumption, and supporting smart land use. Although the High Meadows Fund has not yet explicitly addressed climate change adaptation as a focus, it can be addressed under smart land use.

This is not a source of funding for governments. Rather it is designed for 501(c)(3) organizations. The High Meadows Fund is therefore a resource for local organizations invested in community improvements.

- The Canaday Family Charitable Trust[77]
  The purpose of this trust is to support "not-for-profit organizations that work in Vermont to improve the lives of children and families, promote environmental education and conservation, and preserve the environment."[78] They are willing to support experimental projects. Like the High Meadows Fund, applications for grants regarding climate adaptation could be considered under environmental preservation.

  Like the High Meadows Fund, this money is intended for local organizations that fall under 501 (c)(3).

- The White River Partnership
  The partnership identifies many of their funding partners here: http://www.whiteriverpartnership.org/index.php/about/our-partners. This can be a resource, and a stepping off point for those looking for similar funding sources. Most of these groups do support local organizations and not larger, governmental projects.

- Town Highway Budgets
  Individual municipalities have primary control over their local roads and town budgets. Annually, much transportation work and maintenance is provided for by town management. Town projects and maintenance could integrate adaptive methods into all areas of work, so not adding more expensive methodologies, but adopting adaptive methodologies.

[77] Canaday Family Charitable Trust. http://canadayfamily.org/interest.html.
[78] Ibid.

State Government

On the state level, there are many opportunities for grants or re-appropriation of money to support climate adaptive programs. These include:

- DEC Watershed Management Division: Water Quality Grant Opportunities:[79] These watershed management grants have the possibility of influencing sections of streams or watersheds upstream from transportation infrastructure that could mitigate impacts in future flooding events.

- VTrans: Enhancement Grant Program (as identified in proposed H-770): [80] Section 16 of this proposed bill states that municipal transportation projects "implementing eligible environmental mitigation projects under a river corridor plan" that has been adopted by the ANR will be given preferential weighting for funding.

In regards to disaster aid, VTrans will provide:

- State aid for nonfederal disasters emergencies: an annual appropriation for emergency aid in repairing, building, or rebuilding class 1, 2, or 3 town highways and bridges damaged by natural or man-made disasters

The eligibility criteria for these funds include:

- Disasters which do not qualify for major disaster assistance from FEMA or from the Federal Highway Administration
- Situations where towns will pay 10% of the project, and the state will pay the rest
- For towns that have adopted road and bridge standards, eligibility for reimbursement for repair or replacement of infrastructure shall be to those standards. For towns that have not adopted those standards, eligibility for reimbursement in emergency events will be up to standards

[79] "Water Quality Grant Opportunities." *Watershed Management Division.* Vermont Department of Environmental Conservation. http://www.anr.state.vt.us/dec/waterq/grants.htm.

[80] Vermont. House of Representatives. *Transportation, capital program.* H.770. 2012.

of the infrastructure that pre-existed the event.

This fund is an opportunity for VTrans to re-appropriate and reprioritize allocation of money towards projects that address climate adaptation. The amount of financial support VTrans can provide should be proportional to the extent adaptation is considered. For projects that are incorporating climate adaptation into their plans, VTrans should contribute a greater percentage of the total cost than for projects that do not consider adaptation.

- VTrans Research Board[81]
  Segale identified the Research Board as a possible source for funding of adaptive projects because they already have a system in place for evaluating alternative projects.[82] The Research Section has an opportunity to be innovative and adaptive with their work and really create long-term change.
- State Bridge and Highway Program
  Like the Town Highway Budgets, the State Bridge and Highway Program are an opportunity for integrating adaptive practices into daily management practices.

Federal Government

- Federal Emergency Management Agency (FEMA)[83]
  Most of the money provided by FEMA in disaster events is distributed through the Vermont Emergency Management (VEM). The sources of FEMA money are the Hazard Mitigation Grant Program or the Emergency Management Planning Grants, among others (Section 404 of the Stafford Disaster Relief and Emergency Assistance Act). Ray Doherty of VEM explained that mitigation grants are not specifically designed for climate adaptation, but proposals for funding that address adaptation and the elimination of risk will be considered. For further information on FEMA's funding sources, see Chapter 3.

[81] "Transportation Research Center"
[82] Segale, pers. comm.
[83] For more detail and further sources of federal funding through FEMA, see report section by working group on Repeat Damage.

- National Flood Insurance[84]

  For information on NFIP funding sources, see Chapter 3.
- SAFETEA-LU
- MAP-21

  "MAP-21 consolidates the number of Federal programs by two-thirds, from about 90 programs down to less than 30, to focus resources on key national goals and reduce duplicative programs. It also eliminates earmarks and expedites project delivery while protecting the environment. It creates a new title called 'America Fast Forward,' which strengthens the Transportation Infrastructure Finance and Innovation Program (TIFIA) program to leverage federal dollars further than they have been stretched before. It consolidates certain programs into a focused freight program to improve the movement of goods."[85]

Barriers to Adaptation

There are not policies or plans yet in Vermont that identify the link between climate change adaptation and current actions which already address adaptation. For example, S. 202 one of the bills introduced in the Vermont legislature during the post-Tropical Storm Irene session is designed to minimize flood damage in the future and provide adequate disaster response. Although none of the introduced bills clearly makes a connection to climate change adaptation, each of these bills focuses on adaptation. They address the recovery and reconstruction effort for future flood events – something that will become more common with climate change.[86]

Lack of resources is and will be one of the biggest barriers to adaptation. Both Sue Minter and Noelle Mackay emphasized the lack of manpower in their departments to address climate change adaptation, as much of their focus is on more tangible short-term projects.[87,88] But in this sense, the Agency of Transportation is more proactive than other

[84] For more details on the National Flood Insurance Program, see report section
[85] Summary of Moving Ahead for Progress in the 21st Century MAP-21. US Senate Committee on Environmental and Public Works. PDF.
[86] Vermont. Rivers Bill. Cong. Senate. S. 202. 2012.
[87] Mackay, pers. comm.
[88] Minter, pers. comm.

agencies because it has started to research how climate change will impact transportation infrastructure, as outlined by Campoli's white paper.[89]

A major barrier to climate change adaptation in Vermont is the acceptance that climate change is in fact a real phenomenon that needs to be addressed. Both David Mears[90] and Tim Bouton, Emergency Management Planner for the Addison County Regional Planning Commission,[91] emphasized their hesitance to use the phrase "climate change" with the general public in Vermont. They have found that when attributing events to global climate change, the conversation shifts from the issue at hand and to the existence of climate change. Bouton specifically stated that he instead expresses personal observations—increased severity of rain events or temperature swings (key indicators of climate change identified by Betts and Stager and Thill)—to start discussions on general adaptive practices. For many people who have accepted climate change, it still seems that there is a disconnect between personal observations and the access to the science that makes the connections between the observations and climate science.

Adaptation vs. Mitigation: Controversy or Compromise?

To restate the definitions of mitigation and adaptation mentioned in the introduction, mitigation is the attempt to reduce or limit climate change primarily through minimization of greenhouse gas emissions, whereas adaptation is the concept that regardless of all mitigation efforts, the climate will continue to change in the near future and therefore society will need to adapt to predicted changes.

Minter, Mackay, and Mears all feel that mitigation and adaptation actions should go hand-in-hand. Mears cited floodplain resiliency as a prime example of this because floodplains can limit or diminish the amount of pollution entering larger bodies of water (thus addressing pollution mitigation), and successful floodplains are good adaptive tools for limiting the intensity of floods.[92, 93, 94]

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[89] Campoli, 2011.
[90] Mears, pers. comm.
[91] Bouton, Tim. 2012. Personal Communication.
[92] Minter, pers. comm.
[93] Mears, pers. comm.
[94] Mackay, pers. comm.

F. Transportation Conclusions

By looking both outward at the climate change adaptation suggestions from other state Departments of Transportation and inward at Vermont's own advancements, our investigations have found that it is recommended for Vermont to:

1. Conduct economic and physical risk assessments that account for climate change predictions in the region. Create a central clearinghouse for all the assessment data collected throughout the state and use data to prioritize hazard zones.
2. Coordinate stakeholder adaptation strategies and interests through the Climate Cabinet.
3. Implement structural reforms on existing infrastructure that currently contribute to climate change vulnerability.
4. Incentivize the use of new materials and innovative design for new infrastructure that mitigates damage from events caused by a changing climate.
5. Integrate strategies for ecological protection and resilience in all aspects of transportation action.

In implementing these recommendations Vermont will be furthering its reputation as a leader in the climate change arena by putting into practice recommendations that have yet to be implemented in the majority of the state. These recommendations are all encouraged and supported by federal agencies who provide financial support for their enactment. Adaptation policy to climate change is yet to be a widespread priority across the nation and Vermont has the potential to start what could be a significant trend by successfully introducing such policy.

III. Post-Tropical Storm Irene Implications for Climate Adaptive Housing Policy in Vermont

A. HOUSING POLICY BRIEF: Climate Adaptive Policy for Housing in Post-Irene Vermont, May 2012

Housing presents unique challenges and opportunities, because of its centrality to the human experience and condition, and because of historical development patterns (sprawl, new urbanization, etc.). It is a clear place in which to begin a conversation about adaptation because of the immense economic, social, psychological, emotional and cultural costs of damaged property and displaced populations, but also a challenging one because of its widespread nature and diversity of conditions and circumstances. Opportunities abound, however, to use climate related housing adaptation as a driving impulse for innovation in the realms of urban and rural planning; as a space in which to explore more constrained development patterns (infill housing, for example), as well as principles of social justice (mixed-income communities). It is for these reasons that housing adaptation need play a significant role within adaptation related discourse in post-Tropical Storm Irene Vermont.

Recommendations:

Amend the housing code to: promote, and perhaps mandate, more mixed-income communities to spread social capital more evenly, to promote higher density, infill housing for low-income workers in areas currently served by municipal services, to provide for medium and high density housing along transit corridors, to establish a system for reuse or recycling of construction and demolition materials, particularly for low-income residents pre- or post-disaster, and to facilitate multi-family infill development on formerly commercial and industrial sites while ensuring the health and safety of future residents (Vermont Brownfield Initiative).

Incentivize affordable housing developers to incorporate adaptive measures via: subsidies for adaptive technologies, expedited permit processing for adaptive housing, density bonuses or other incentives for innovations in adaptive housing, technical assistance programs regarding energy codes and energy efficiency, and education and awareness for do-it-yourself suppliers regarding adaptation.

Adopt an ordinance to facilitate the conversion of old, abandoned downtown office buildings into housing ideally through the Vermont Department of Housing and Community Affairs' Downtown Program.

Conduct risk assessment for vulnerable homes and prioritize the results for planned adaptation related action using the principles of the Fair Housing Equity Assessment.

Integrate adaptation into retrofitting using revenue generated from residential electricity bills and pre-appropriated funding for greenhouse gas reduction and energy efficiency promotion to incorporate an adaptation skill set into home retrofitting and other efficiency measures.

Persuade the public of why and how to adapt, by emphasizing quality of life improvements both present and future. Build messaging into communications where mitigation is already being discussed, provide information on personal risk, access to advice, economic benefits of adaptation, reach the next generation of householders and professionals through schools and universities, place special emphasis on vulnerable stakeholders (and programs already implemented to support them), and empower individuals to conduct personal risk assessment (tools, expert advice, etc.).

Investigate measures external to the home like porous paving or open structures on driveways (Sustainable Drainage Systems), green roofs, rainwater harvesting, ensuring that flood pathways on driveways enable drainage away from home.

Encourage greater participation in the National Flood Insurance Program in towns already participating, and for towns not yet participating, especially pending passage of S. 202.

Cost

Adaptation risk assessment, policy planning and implementation, and outreach will all require funds over and above those already afforded by the Vermont Department for Housing and Community Development. Luckily, ample funds for housing related adaptation exist within Federal agencies—namely, the Department for Housing and Urban Development, the Department of Transportation and the Environmental Protection Agency. All offer substantial grant programs for innovation in the fields of rural and urban housing and transportation planning, as pertaining to climate vulnerability, greenhouse gas intensity, and accessibility to shared transportation and necessary services and amenities. Examples and resources for further exploration of them are included below.

In June 2009, the U.S Department of Housing and Urban Development, the Department of Transportation and the Environmental Protection Agency joined together to form the Partnership for Sustainable Communities, an unprecedented agreement to coordinate federal housing, transportation and environmental investments, protect public health and the environment, promote equitable development, and help address the challenges of climate change. The Partnership is based on the key principles of development on formerly marginalized land, mixed-use and mixed-income housing, and transportation accessibility.

Tapping into both funds appropriated to HUD and to the Department of Transportation (Tiger II Planning Grants), the Partnership announced a series of grants and other assistance totaling $409.5 million in funding in 2011, to support more livable and sustainable communities. The Sustainable Communities Regional Planning Grant Program supports metropolitan and multi-jurisdictional planning efforts that integrate housing, land use, economic and workforce development, transportation, and infrastructure investments in a manner that empowers jurisdictions to consider the interdependent challenges of: (1) economic competitiveness and revitalization; (2) social equity, inclusion, and access to opportunity; (3) energy use and climate change; and (4) public health and environmental impact.

To support the work of grantees of the Partnership for Sustainable Communities, the Consolidated Planning Enhancement Initiative of HUD's Office of Community Planning and Development is also leading an effort to improve climate change adaptation at the state and local government level, by providing technical assistance for needs and risk assessments, as well as guidance for funding priorities, implementation schemes, etc.

The EPA's Smart Growth Implementation Assistance Program, in its prioritization of "historic preservation and downtown revitalization and climate change adaptation" could also offer financial resources for housing related adaptation priorities in Vermont. "The SGIA program is an annual, competitive solicitation open to state, local, regional, and tribal governments (and non-profits that have partnered with a governmental entity) that want to incorporate smart growth techniques into their future development.

Vermont as a Leader

Since more efficient use of space, reductions in sprawl, and greater utilization of existing road and transportation networks are measures that overlap greatly with the goals of reducing energy consumption and increasing efficiency, there are no foreseeable contradictions between mitigation and adaptive housing when it comes to transportation—only opportunities for synergy. For this reason, Vermont's already elevated status as a leader on climate change mitigation will only help to serve as an ideal launching point for housing adaptation policy going forward.

B. Effects of Climate Change on Housing Infrastructure

Flooding, decreased water availability, and heat waves are among those climate change impacts most likely to affect housing, particularly low-income households. Flooding not only destroys carpeting, electrical wiring, plumbing systems, and entry-level furniture and belongings, but carries with it the potential to do much psychological harm by ruining materials with great sentimental value, as well as permanently damaging spaces in which individuals spend a great deal of time and typically derive great comfort. Decreased water availability and heat waves typically pose great health concerns, and their impacts are greatly accentuated among lower-income households because of limited access to air conditioned spaces and bottled water.

C. General Recommendations

The following recommendations, in the absence of meaningful action on housing-related adaptation at the state level, have been derived in great part from the knowledge and practice currently being formulated at the federal level. It is worth noting, however, that because of the wide array of funding opportunities for state based action, little prevents these federally designed recommendations from being pursued and implemented. Vermont's leadership on broader environmental and climatic principles only serves to underscore this potential for action in this state.

A. Recognizing that the current housing code does not encourage special consideration of climate change adaptation, particularly for those households and housing types vulnerable to the predicted impacts of climate change, amend the housing code to:[1]

- Promote, and perhaps mandate, mixed-income communities to spread social capital more evenly.
- Promote higher density, infill housing for low-income workers in areas currently served by municipal services, and consistent with existing neighborhood or commercial district patterns
- Provide for medium and high density housing along transit corridors

[1] Department of Housing and Urban Development Policy Statement for Climate Change Adaptation, Released April 2009

- Establish system for reuse or recycling of construction and demolition materials, particularly for low-income residents pre- or post-disaster
- Facilitate multi-family infill development on formerly commercial and industrial sites while ensuring the health and safety of future residents (brownfields)

B. Recognizing that various untapped / underutilized resources for housing developers currently exist, incentivize affordable housing developers to incorporate adaptive measures via:[2]

- Subsidies for adaptive technologies
- Expedited permit processing for adaptive housing
- Density bonuses or other incentives for innovations in adaptive housing
- Technical assistance program with energy codes and energy efficiency
- Education and awareness for do-it-yourself suppliers regarding adaptation

C. Recognizing the flexibility of space, adopt an ordinance to facilitate the conversion of old, abandoned downtown office buildings into housing[3]

D. Recognizing that adaptation should be integrated with the carbon reduction agenda for homes, integrate adaptation into retrofitting

- Use revenue generated from residential electricity bills, and pre-appropriated funding for greenhouse gas reduction and energy efficiency promotion to incorporate an adaptation skill set into home retrofitting and other efficiency measures

E. Recognizing the potential to empower households to take adaptation into their own hands, fund, plan and implement a campaign to inform and persuade the public of why and how to adapt[4]

- Emphasize quality of life improvements both present and future
- Build into communications where mitigation is already being discussed

[2] California Department of Housing and Community Development: Housing Element Policies and Programs Addressing Climate Change, February 2009
[3] Your House in a Warming Climate, Retrofitting Existing Homes for Climate Change Impacts (Report for Policy Makers). Three Regions Climate Change Group, February 2008
[4] Your House in a Warming Climate, Retrofitting Existing Homes for Climate Change Impacts (Report for Policy Makers). Three Regions Climate Change Group, February 2008

- Provide information on personal risk, access advice, economic benefits of adaptation
- Reach the next generation of householders and professionals through schools and universities
- Place special emphasis on vulnerable stakeholders (and programs already implemented to support them)
- Empower individuals to conduct personal risk assessment (tools, expert advice, etc.)

Tactics:

- Letters and leaflets to households
- Speaker program to schools, rotary clubs, environmental groups, neighborhood watch and community housing associations
- Promotional campaigns through local press and radio giving away gateway adaptation goods
- Information packets for schools
- Integrated advertising in newspapers, washrooms, radio, billboards, buses, online, and product placements on TV

F. Recognizing the disproportionate climate burden borne by low income households, conduct risk assessment for vulnerable homes and prioritize the results for planned adaptation related action:[5]

- Include non-financial costs of home damage (distress, inconvenience, sentimental value)
- Establish new building codes and programs based on findings
- Tailor educational programs and outreach materials toward the urgency of the particularly vulnerable

G. Recognizing the immense potential to mitigate the effects of climate change outside of conventional home structures, investigate external measures:[6]

- Porous paving or open structures on driveways (Sustainable Drainage Systems)
- Green roofs

[5] Partnership for Sustainable Communities, February 2011 Fact Sheet on Awarded Grants From 2010
[6] Pew Center for Climate Change, "Climate Change Adaptation: What Federal Agencies Are Doing." February 2012 Update.

- Rainwater harvesting
- Ensuring that flood pathways on driveways enable drainage away from home

<u>H. Recognizing that the majority of Vermont towns currently participate in the National Flood Insurance Program, encourage greater household participation in National Flood Insurance Program</u>

- Conduct outreach among communities participating in the program already, and encourage those towns not participating to join (Figure 3).

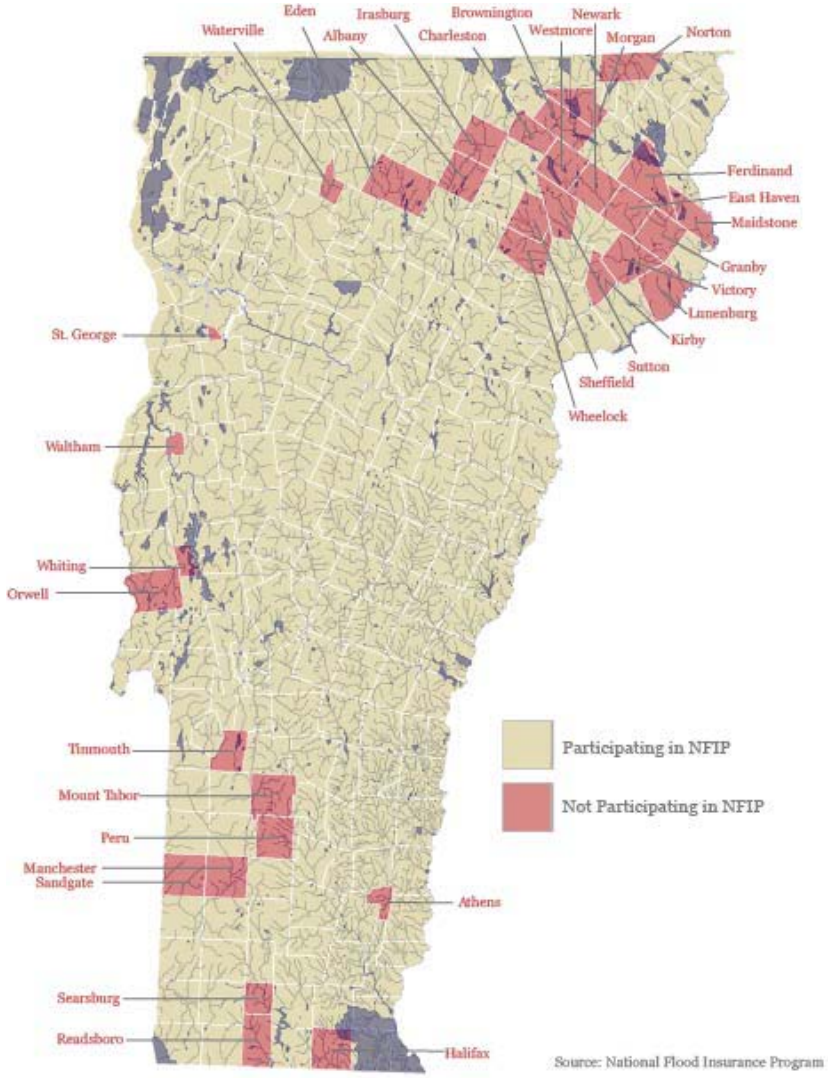

Figure 3. Participation by Vermont towns in the National Flood Insurance Program. Adapted from information from http://www.fema.gov/cis/VT.html.

D. Risk Assessment and Implementation Framework

Why Adapt?

In a world where climate change mitigation carried salience among those nations most responsible for the long-term (the United States, Canada, Australia, Japan, India, China, the EU, etc.), adaptation would not require great attention. Nonetheless, in the context of widespread climate intransigence, and recognizing the already-present nature of climate change across the globe, adaptation is a necessary and arguably more salient conversation than that of mitigation at the governmental level.

Housing presents unique challenges and opportunities because of its centrality to the human experience and condition and because of historical development patterns (sprawl, new urbanization, etc.). It is an obvious place in which to begin a conversation about adaptation because of the immense economic, social, psychological, emotional and cultural costs of damaged property and displaced populations. Housing also represents a challenging place to start a conversation about adaptation because of its widespread nature and diversity of conditions and circumstances. Opportunities abound, however, to use climate related housing adaptation as a driving impulse for innovation in the realms of urban and rural planning; as a space in which to explore more constrained development patterns (infill housing, for example), as well as principles of social justice (mixed-income communities). This can be a plausible path to take considering the many grants given to housing projects and environmental projects.

When to Adapt

The time period immediately following floods or heat waves are ideal times to promote do-it-yourself adaptation measures. This context allows for conducting risk assessments, policy changes, building code amendments, and financing schemes. Adaptation measures should especially be considered immediately after a natural disaster event given that otherwise people will bounce back to the status quo, re-building their houses in flood prone areas and without consideration of environmentally sound building alternatives. These measures should, however, continuously be developed and tweaked in the context of successes and failures, in order to maximize climate preparedness.

How to Adapt

Adaptation must be lead by government, landlords from the social and private sectors, owner-occupiers, do-it-yourself suppliers, and associated professionals. Together, they can transform housing markets, building codes, and prevailing psychologies (see Chapter 4), to consequently create more sustainable individual structures, and more sustainable collective communities (mixed-income, mixed-use, in well situated transportation corridors, infill housing, etc.).[7]

Cross-departmental collaboration will be necessary to take full advantage of federal funding opportunities for housing innovation in the realm of climate change, and to begin a dialogue where transportation networks, access to amenities and services, historical patterns of development and sprawl, the health and safety of residents, and the financial and non-financial costs of climate impacts on housing and personal property can comprehensibly be taken into consideration.

Flood adaptation offers all residents two prevailing pathways: the first, resistance: the prevention or limitation of the amounts of water entering the home, and the second: the reduction of the time and cost of recovering from disasters. The former is ideal for those unable to attain flood insurance and can be undertaken during any pre-disaster time, while the latter might only be undertaken before a specific, expected disaster. Both possess components that in the long-term need be mandated through housing codes, for all resident demographics and housing types. Educational campaigns to promote do-it-yourself adaptive measures, and to encourage market transformation through consumption of adaptive technologies, could play a large role in Vermont's housing related adaptation strategy.[8]

Resistance:

- All potential entry points identified and blocked
- Doors, air bricks, sinks and toilets, gaps in external walls around pipes and cables
- Repair damaged mortar, install waterproof membranes or renders
- Drainage bungs for drains, sinks and toilets
- Airbrick covers
- Seal gaps around pipe and cable entries

[7] Federal Highway Administration Fact Sheet on Disaster and Climate Management, April 2010.
[8] Your House in a Warming Climate, Retrofitting Existing Homes for Climate Change Impacts (Report for Policy Makers). Three Regions Climate Change Group, February 2008

- Fit non-return valves on main drains
- Demountable door guards installation
- Move meters and electrical sockets above floor levels
- Raise door thresholds
- Re-point brickwork on external walls
- Apply waterproof render to walls
- Install waterproof membranes on external walls

Note: In deep floods (over 35in), imbalance between external and internal water levels can cause structural damage to walls, may be necessary for water to enter

Resilience:

- Store valuables and paperwork upstairs (need an upstairs for that)
- Turn off gas, water and electricity mains
- Fit rising hinges so doors can be removed
- Use dry-bags to protect soft furnishings
- Use water-resistant paint for the lower portions of internal walls
- Rewire, raising electrical points above flood level (with wiring drops from above)
- Relocate meters and boiler above flood level
- Relocate white goods on a plinth above floor level
- Replace carpets with vinyl and ceramic tiles or rugs
- Replace timber floors with solid concrete

How Much to Adapt

The Fair Housing Equity Assessment (FHEA) – a program of the Federal Department for Housing and Urban Development's Office of Sustainable Housing and Communities (HUD – OSHC) – includes the following assessment components, and is therefore a useful tool in assessing how much to adapt, at least in the context of the marginalized, dispossessed and underprivileged (those facing the greatest impediments to housing acquisition): [9]

- Segregated Areas and Areas of Increasing Diversity and/or Racial/Ethnic Integration
- Concentrated Areas of Poverty
- Access to Existing Areas of High Opportunity
- Major Public Investments
- Fair Housing Issues, Services and Activities

[9] Fair Housing Equity Assessment, Office of Sustainable Housing and Communities, Department of Housing and Urban Development, WASHINGTON, DC 20410-0050, January 2012

Grantees of the program are asked to focus their analysis at the regional scale across these components, comparing within and across jurisdictions to gain a full picture of regional equity and access to opportunity. Steps for grantees are as follows:

- Set up an approach to the FHEA, that includes a bridge from assessment findings to strategy development, priority setting and investment in solutions in addition to discussing a timeline for assessment and implementation (though no absolute deadline is imposed).
- Use provided data and data tools to analyze impediments to housing acquisition and sustainability (climate context).
- Construct product for FHEA or integrate content of the FHEA into other documents (final regional plan).
- Submit all findings and 'bridge' policies to a regional oversight group.

Who Should Adapt

If an FHEA is identified as desirable to undertake, it should determine who should be targeted for adaptation outreach or policy programs first and foremost, however in the long-term, building codes for all housing demographics and all existing structures should be perceived as needing attention on the subject of adaptation. Arguably, wealthy, seemingly non-vulnerable populations can be as, if not more worthy of adaptation outreach because of the false confidence of wealth or location. Ultimately, we are all vulnerable and therefore we should all adapt.

Cost of Adaptation

Examples and resources at the federal level to fund adaptation to climate change in the housing sector are detailed below.

In June 2009, the U.S Department of Housing and Urban Development, the Department of Transportation and the Environmental Protection Agency joined together to form the Partnership for Sustainable Communities, an unprecedented agreement to coordinate federal housing, transportation and environmental investments, protect public health and the environment, promote equitable development, and help address the challenges of climate change. The Partnership is based on the key principles of development on formerly marginalized land, mixed-use and mixed-income housing, and transportation accessibility.[10]

[10] See: https://www.fhwa.dot.gov/livability/partnerships/

Thus far, HUD has also revised its policies to make it easier for Federal Housing Administration-insured multifamily housing to be developed on formerly commercial and industrial sites while ensuring the health and safety of future residents. This will allow sites that are often aptly-located but off limits to development to be reclaimed and revitalized to provide affordable housing near transit stations and other amenities. EPA, HUD and DOT are working together to identify sites and ensure sustainable cleanup and redevelopment.

Tapping into both funds appropriated to HUD and to the Department of Transportation (Tiger II Planning Grants), the Partnership announced a series of grants and other assistance totaling $409.5 million in funding in 2011, to support more livable and sustainable communities. "The Sustainable Communities Regional Planning Grant Program supports metropolitan and multi-jurisdictional planning efforts that integrate housing, land use, economic and workforce development, transportation, and infrastructure investments in a manner that empowers jurisdictions to consider the interdependent challenges of: (1) economic competitiveness and revitalization; (2) social equity, inclusion, and access to opportunity; (3) energy use and climate change; and (4) public health and environmental impact. The Program places a priority on investing in partnerships, including non-traditional partnerships (e.g., arts and culture, recreation, public health, food systems, regional planning agencies and public education entities) that translate the Federal Liveability Principles into strategies that direct long-term development and reinvestment, demonstrate a commitment to addressing issues of regional significance, use data to set and monitor progress toward performance goals, and engage stakeholders and residents in meaningful decision-making roles."[11]

To support the work of grantees of the Partnership for Sustainable Communities, the Consolidated Planning Enhancement Initiative of HUD's Office of Community Planning and Development is also leading an effort to improve climate change adaptation at the state and local government level, by providing technical assistance for needs and risk assessments, as well as guidance for funding priorities, implementation schemes, etc.[12]

The EPA's Smart Growth Implementation Assistance Program, in its prioritization of "historic preservation and downtown revitalization and climate change adaptation" could also

[11] See: http://portal.hud.gov/hudportal/HUD?src=/program_offices/sustainable_housing_communities/sustainable_communities_regional_planning_grants

[12] See: http://portal.hud.gov/hudportal/HUD?src=/open/innovation_ideas_in_action/consolidated_plan_enhancements

offer financial resources for housing related adaptation priorities in Vermont. “The SGIA program is an annual, competitive solicitation open to state, local, regional, and tribal governments (and non-profits that have partnered with a governmental entity) that want to incorporate smart growth techniques into their future development.

Once selected, communities receive direct technical assistance from a team of national experts in one of two areas: policy analysis (e.g., reviewing state and local codes, school siting guidelines, transportation policies, etc.) or public participatory processes (e.g., visioning, design workshops, alternative analysis, build-out analysis, etc.). The assistance is tailored to the community's unique situation and priorities. EPA provides the assistance through a contractor team – not a grant. Through a multiple-day site visit and a detailed final report, the multi-disciplinary teams provide information to help the community achieve its goal of encouraging growth that fosters economic progress and environmental protection.

EPA initiated the SGIA program in 2005 with three goals in mind:

- To support communities interested in implementing smart growth policies.
- To create regional examples of smart growth that can catalyze similar projects in the area.
- To identify common barriers and opportunities for smart growth development and create new tools that other communities can use.”[13]

Another resource is HOME , a program that could also provide with a grant in order to help build toward adaptation in the housing sector. “HOME is the largest Federal block grant to State and local governments designed exclusively to create affordable housing for low-income households. Each year it allocates approximately $2 billion among the States and hundreds of localities nationwide. The program was designed to reinforce several important values and principles of community development:

- HOME's flexibility empowers people and communities to design and implement strategies tailored to their own needs and priorities.
- HOME's emphasis on consolidated planning expands and strengthens partnerships among all levels of government and the private sector in the development of affordable housing.

[13] See: http://www.epa.gov/smartgrowth/sgia.htm

- HOME's technical assistance activities and set-aside for qualified community-based nonprofit housing groups builds the capacity of these partners.
- HOME's requirement that participating jurisdictions (PJs) match 25 cents of every dollar in program funds mobilizes community resources in support of affordable housing."[14]

Barriers to Adaptation

Ultimately, funding constraints are the most surmountable barriers to adaptation considerations for housing planning in Vermont, whereas fragmented authority over rural and urban community planning pose the greatest challenges with no foreseeable solution, beyond institutional flexibility and diverse collaboration. In order for Vermont to plan mixed-income and/or infill communities of greater resilience and resistance to climate impacts, and to adapt existing structures to the pressures of climate change, inter-agency dialogue to determine areas of overlap as well as elucidate foreseeable challenges to action will be necessary.

A great deal can be learned from cities and regions who have received federal money to innovate with rural and urban transportation and housing planning; however, Vermont's unique demographics and the baseline challenges of generalizing a process so deeply dependent on the details (on the cultural, social, economic and physical geography of a place) must also be remembered when examining the past and present behavior of other places attempting to address similar problems.

Contradictions with Mitigation Policy

Since more efficient use of space, reductions in sprawl, and greater utilization of existing road and transportation networks are measures that overlap greatly with the goals of reducing energy consumption and increasing efficiency, there are no foreseeable contradictions between mitigation and adaptation housing when it comes to transportation – only opportunities for synergy.

[14] See: http://www.hud.gov/offices/cpd/affordablehousing/programs/home/

E. Risk Assessment and Implementation Framework Specific to Vermont

Why Adapt

Vermont as an environmental leader state has done a lot of work to mitigate climate change and GHG emissions. Vermont, moreover, has joined regional efforts and is a member of the Regional Greenhouse Gases Initiative (RGGI). RGGI is a program of the Climate Change Action Plan of New England and Eastern Canadian territories, RGGI represented the first U.S. cap-and-trade program for power plant emissions of CO2.[15] In terms of adaptation, however, there has been little development on adaptation measures to counteract the effects of climate change. After Tropical Storm Irene, Vermont has come to realize the need to adapt to more frequent and intense natural events such as flooding. The housing sector was specially affected, with entire houses being dragged out of their foundations and mobile homes completely destroyed.

When to Adapt

Ultimately, the impacts of climate change are already being felt (most recently during and in the aftermath of Tropical Storm Irene) and adaptation on housing – such a central component to the human experience – should not be delayed. Action regarding those households most vulnerable to climate change (low-income and floodplain residents, often one and the same) should take priority in the short term, while long-term measures to encourage adaptive measures for all demographics of households are planned and undertaken. Innovative funding mechanisms and cross-departmental collaboration will be necessary.

How to Adapt

In order to make medium and high density housing along transit corridors a good adaptation measure, partnership with the transportation sector will also be necessary. The location of many roads in Vermont has proven not to be optimal; sometimes they are built at the expense of channeling rivers out of their otherwise regular migration patterns.

Even though it is not considered an adaptation measure, Vermont has developed projects to incentivize mixed-income communities in urban areas with easy access to commerce and services. “On October 27, 2011, the Rutland Housing Authority (RHA) and Housing Vermont unveiled seven new buildings with a total of 33 apartments off Forest Street in Rutland’s

[15] See: http://www.rggi.org/

southwest neighborhood. The buildings at the new Hickory Street Apartments range in size from duplex structures to a building with 12 apartments."[16] The rent for the apartments ranges from $665 for a one-bedroom unit to $1,019 for a three-bedroom apartment, including heat and hot water. People with low incomes who cannot afford the lowest rent are eligible for rental assistance. We suggest that this might represent an opportunity for the state government to further partner with this organization or type of organization. In this way the state can provide subsidies to incorporate adaptive measures or any other type of incentives to achieve this goal.

More of these mixed-income housing projects could be possible in Vermont through the Vermont Brownfields Initiative. This initiative is "a collaboration of the Agency of Commerce and Community Development (ACCD) and the Agency of Natural Resources (ANR). Combining the economic and community development expertise of ACCD with the technical environmental review functions of ANR will expedite the clean- up of vacant, contaminated sites and implement productive re-use projects,"[17] including housing developments. This initiative accounts for two new funding sources that will be awarded to successful projects. Funding will come from the ACCD's Vermont Community Development Program as well as from The Brownfields Revitalization Fund (BRF) for redevelopment projects. Moreover, "The Vermont Redevelopment of Contaminated Properties Program (RCPP) administered by the ANR Department of Environmental Conservation allows a prospective purchaser to acquire and clean up a contaminated property in exchange for receiving liability protection."[18]

Furthermore, there are other state level initiatives that can help develop affordable housing while serving the purpose of avoiding sprawl such the Downtown Program of the Vermont Department of Housing and Community Affairs. This is an initiative to revitalize the downtown areas of villages and cities. The program aims to fill abandoned buildings and commercial spaces by attracting new business, investment and other ways of enhancing the vitality of Vermont's downtowns.[19] This program can be the venue to reinforce the development of housing in the downtown areas.

Through all of these projects, affordable housing can be developed, especially for those with the lowest income who have being in many cases forced by their economic condition to

[16] See: http://www.hvt.org/housing-vermont/hv-and-rha-celebrate-the-opening-of-hickory-street-apartments/
[17] See: http://www.dhca.state.vt.us/brownfields/index.htm
[18] See: http://www.dhca.state.vt.us/brownfields/index.htm
[19] See: http://www.historicvermont.org/programs/downtown.html

settle in floodplains and flood prone areas. This would, moreover, greatly benefit mobile home owners, who were especially hard hit by Tropical Storm Irene.

While the Vermont Agency of Natural Resources Waste Management Division currently does not provide direct assistance with construction waste management, it does provide information on how to do it.[20] This division, however, can be proposed to be established as the entity in charge of construction material recycling and reuse in emergency cases, such as devastating floods. In this way more affordable material would be available to low-income families for reconstruction purposes, at least as an immediate response measure.

Moreover, in order to build to adapt to climatic changes we need to implement housing adaptive technologies. Even though the Vermont government does not provide financial assistance with this particular adaptive measure, there are non-profit organizations such as the "Vermont Green Building Network" that provide workshops for the community on do-it-yourself ways of building in adaptive and environmentally sound ways.[21]

Further, it is important to take into consideration other measures to adapt to climate change, such as the weatherization of Vermont's residencies. Vermont has already taken up on the issue through its Weatherization Program, which is "designed to help low income residents — particularly older Vermonters, people with disabilities, and families with children — to save fuel and money by improving the energy efficiency of their homes.[22] On this topic, Vermont's legislature has passed H. 436, which gives tax incentives for those companies that implement weatherization to low income houses.

When thinking about adaptation measures in the event of flooding, it is important to encourage towns in Vermont to participate in the National Flood Insurance Program, while recognizing the caveats shared in Chapter 3. Senate Bill 202, which has passed in the Senate and is in the House of Representatives includes:

- ensuring that the development of the flood hazard areas of this state is accomplished in a manner consistent with the health, safety, and local, management activities for flood hazards areas;
- complying with the National Flood Insurance Program requirements for the regulation of development; among others.[23]

[20] See: http://www.anr.state.vt.us/dec/wastediv/recycling/CandD.htm
[21] See: http://elite218.inmotionhosting.com/~vgbn/page.php?pid=47&pname=what-we-do
[22] See: http://dcf.vermont.gov/oeo/weatherization
[23] See: http://www.leg.state.vt.us/docs/2012/bills/Passed/S-202.pdf

This bill, even though not directly aimed at the housing sector, will entail encouraging more strict municipal land use regulation of nonexempt development to minimize the risk of potential damage to housing. For instance, this would ideally regulate the settlement of low income housing, such as mobile home projects, on land prone to flooding.

How Much to Adapt

The Fair Housing Equity Assessment (FHEA) poses a set of components that could be useful to identify how much to adapt in the context of less privileged communities. In the context of Vermont, however, it will also important to recognize certain state and community specific factors, such as where is the residence or the community settled. In the context of more frequent and intense floods, residents have to adapt as much as it will be needed in this scenario.

Who Should Adapt

Given the high likelihood that Vermont will experience more frequent and intense flood events, everyone in the state should be prepared and adapt to the damage their properties might incur. However, people living on floodplains, in mobile homes, and those with low income should be prioritized.

Cost of Adaptation

Adaptation risk assessment, policy planning and implementation, and outreach will all require funds over and above those already afforded by the Vermont Department for Housing and Community Development and Department of Transportation. Luckily, ample funds for housing related adaptation exist within Federal agencies – namely, the Department for Housing and Urban Development, Department of Transportation and the Environmental Protection Agency. All offer substantial grant programs for innovation in the fields of rural and urban housing and transportation planning, as pertaining to climate vulnerability, greenhouse gas intensity, and accessibility to shared transportation and necessary services and amenities.

Federal funding will be crucial for the development and implementation of adaptive measures. There are, moreover, local initiatives at the state level that could enhance the implementation of our recommendations. One of the resources found in the state is Housing Vermont, a non-profit development company that has provided affordable rental housing for Vermonters since 1988 through partnerships with local organizations, public agencies and the private sector. Through their partnerships, Housing Vermont has provided more than 4,400

affordable apartments through their fundraising efforts that amount to more than $247 million in private equity and $351 million in private and public investment.[24]

Barriers to Adaptation

As mentioned above, one of the major barriers that we encountered is how to fund adaptation measures. We have found, however, that there are sources of funding that can help implement adaptive changes to the housing infrastructure in Vermont. It is important also to recognize the jurisdiction given to municipalities in Vermont. Communication between the state government and the municipalities will be key in order to best deal with the adequate procedures to withstand the consequences of a changing climate. Moreover, the notion of climate change adaptation has very high salience at the state government level, but it is not always the case at the local level as shown by the surveys conducted for this report. This difference of opinion or perception can hamper the sense of urgency when dealing with climate change consequences.

F. Housing Conclusions

The Vermont government is well aware of the need and urgency to implement adaptation measures in the face of climate change. Many members of the community do not, on the other hand, recognize the connection between increasing intensity and frequency of floods and climate change, sometimes not even those who were most hard-hit (see Chapter 4). Tropical Storm Irene did show however, that there are changes happening in the climatic patterns, making the issue more tangible and real.

During the 2011-2012 legislative session, members of Congress recognized the need to include adaptation measures into legislation. We further emphasize the need for improved communication between the different stakeholders, as well as putting human capital towards utilizing the financial support and funding that we considered relevant to the development of the above-mentioned adaptive housing recommendations.

[24] See: http://www.hvt.org/

6. Conclusion

Greater frequency of repeat damage assessment, more intense and long-term coordination between state agencies and community planners, pursuit of federal funding options and a paradigm shift toward the crux of housing, transportation, rivers and people can be those phenomena which fundamentally alter the climate risk Vermonters are currently shouldering. Synergies regarding long-term river management practices and the locations and intended beneficiaries of housing and transportation networks could dramatically adjust the distribution of social capital in the state, warn residents of long-term risk all the while providing preferential options and using available funding in a manner that increases infrastructural resilience. All of this is of course, is contingent upon a struggle to overcome chronic human myopia—to avoid the natural tendency to (and precedent of) returning to the status quo in the wake of a climate disaster. But this report demonstrates not only that unique and diverse sources of funding are available, but also that Vermonter's possess the necessary social capital, communitarian ethic, and motivation at the state agency level to usher in a new era of policy planning and implementation.

We cannot extend enough thanks to our community partners for their support throughout this work, and we are deeply hopeful that this report plays a supporting role in their work going forward.